DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Trends in Chemical Production

ACCORDING to the latest O.E.E.C. report* chemical production in Britain was 3% higher in 1956 than in 1955. This was a smaller rise than in the previous year when production had gained 7% on 1954. It was also smaller than the average figure for the member countries of O.E.E.C., which was 8%. The trend in British chemicals may however be compared with that for our industry as a whole where production declined by about 1% over the same period reflecting to some extent the financial measures taken by the government. However, in the first six months of 1957 the British chemical industry increased its output by 9% over the first half of 1956 reaching an index of 133 compared with 1953 at 100. Over the same period the index of total industrial production hardly changed. For the whole of the O.E.E.C. area the 8% increase in chemical production in 1956 quoted above, represented a slightly lower rate than that in 1955 which was 11.5% The rate of increase of the national product and of all industrial production, at about 4% each for the whole area, also diminished by comparison with the preceding years. These comparisons amply justify the description of the chemical industry in the report as "one of the most dynamic in Europe".

This is a valuable series of reports analysing the market situation for this group of countries including factors in supply and the trends in demand and price. There are also reviews of international trade and trends in productivity. Analyses are provided by country and by sector such as basic chemicals, petroleum chemicals, fertilisers and so on. The treatment is marred only by the looseness in the use of the expression "European" which sometimes makes it difficult to understand whether geographical Europe or the O.E.E.C. area is being referred to. This criticism of course does not apply to the excellent statistical annexes.

* The Chemical Industry in Europe. Fourth Year. Organisation for European Economic Cooperation. 1957.

Analysis of Explosion of a Large Refinery Unit

IT has often been observed that engineers are shy of publishing their most valuable experience—the accidents and the failures. One complete session of the Annual Meeting of the American Institute of Chemical Engineers comprising five brave papers was, nevertheless, devoted to shock waves in process equipment and fell partly under this heading. Destruction of a large refining unit by explosion was discussed by R. B. Jacobs and colleagues. Apparently in August 1955, a large fluid hydroformer at Whiting, Indiana, was seriously damaged by a number of internal explosions. The principal explosions occurred within the reactor vessel and a high pressure separator, completely destroying these. Lesser explosions occurred in accessory plant.

The violence of the explosions in the reactor and separator drum was sufficient to cause extensive fracturing. The fragments, particularly those from the reactor, were scattered over an area of about 1,200 feet radius resulting in numerous fires. The disaster was thoroughly investigated from two aspects. The first was the determination of the exact sequence of events which produced the flammable mixture and its subsequent ignition. It was found that through accident a flammable mixture was produced in certain parts of the unit, including the reactor vessel. Ignition probably occurred on the heated surfaces of the furnace tubes in the recycle gas circuit. The second aspect, reconstruction of the disaster from the scattered and often fragmentary evidence, was more difficult. How could a mixture of hydrocarbons and air generate sufficient destructive violence to shatter the reactor and hurl it apart? Calculations of the explosive pressure made by the usual methods would predict, under the conditions which existed, that the reactor should not have failed; furthermore, the calculated available energy fell somewhat short of that needed to hurl the fragments by the most efficient probable mechanism. It was also puzzling that two almost equally violent explosions occurred a number of seconds apart.

The clue lay in the existence of shock waves in the principal vessels and lines. Metallurgical evidence obtained from careful examination of the wreckage enabled the location of the shock wave front at the time of rupture to be determined in the principal vessel. Through both the location of Luders lines and the position of unit parts, the direction of flame travel was established. These facts, coupled with the known properties of detonations, enabled the sequence of events after ignition to be reconstructed.

New Vacancy List for Chemical Engineers

SQUARE pegs should be helped to find square holes by the new vacancy list diary of the Institution of Chemical Engineers. The service has been launched in response to numerous requests from industry for help with their recruitment problems. The list will be issued monthly announcing both vacancies and notices which cannot await publication in "The Chemical Engineer". In the official announcement, Dr. J. Brennan, General Secretary of the Institution, suggests that this new service will be warmly welcomed by members and by industry—by members because vacancies for chemical engineers may be found in their own journal, and by industry because all qualified chemical engineers, as well as a large number of chemical engineers in training, can be reached by one insertion. It is the latter class of member which contains those young men most likely to be seeking fresh employment. By using this list it should become possible to reach virtually all chemical engineers with only one announcement, thereby enabling a considerable saving in

cost to be made; in addition the rates are lower than those of the national newspapers which specialise in advertising vacancies for technologists.

Zeta

HOW puny seem all other insulation problems compared with those of maintaining temperatures of millions of degrees. The revolutionary approach that made this possible is discussed in a group of papers in "Nature", 25th January, 1958. In addition the thermonuclear machine Zeta in which this occurred was recently shown to the press. All the workers in this field are relying on the invisible insulation produced by forming a "pinched" discharge stabilised by an axial magnetic field. The gas in the current channel is compressed away from the walls. In Zeta, electrical discharge takes place in an aluminium torus of 1 metre bore and 3 metres mean diameter, containing deuterium gas at low pressure. This tube is linked by the iron core of a large pulse transformer. A current pulse of electricity is passed into the primary winding of the transformer from a bank of capacitors capable of storing 500,000 joules of energy. The pulse in turn induces a very large unidirectional pulse of current in the gas, which forms a short-circuited secondary for the transformer. Peak currents up to 200,000 amperes have been passed through the ionised gas for periods up to 5 milliseconds. Temperatures are measured by mixing in oxygen or nitrogen which retain electrons under these conditions and therefore give a line spectrum. Broadening of these lines due to the Döppler effect associated with the random motion of these atoms is then used to measure the temperature. At present the ratio of energy output to input is 10^{-12}— hence the title "zero energy". The high temperatures achieved in Zeta, and the relatively long duration for which the hot gas has been isolated from the tube walls are the most important experimental results obtained so far. Whilst a much longer time (perhaps several seconds) is required for a useful power output there appears to be no fundamental reason why these longer times, together with much higher temperatures, cannot be achieved. Work has already started on modifications to Zeta to make it possible to attain the higher temperatures. Future plans include constructing a prototype of a practical thermonuclear power station. Research workers at Harwell stated that electricity might be drawn off by induction from the discharge in the torus and by neutron-actuated batteries as well as by the conventional thermal steam-raising off the heated chamber walls.

"Plain men"—to whom it is addressed—will find the Manchester Guardian's shilling booklet a handy guide to Zeta and its significance.

Design of Reactors

AT the heart of the chemical industry lies the reactor. In fact the life of the industry depends on the possibility of carrying through reactions economically. This is the theme of a valuable paper by E. Mertens de Wilmars which opens with a review of past studies on classification systems and methods of calculating reactors then goes on to discuss certain detailed problems. In particular two calculated examples are given. One of them is devoted to operations in the liquid phase, both in continuous operation and during the transition periods. The other deals with a reactor operated in the gaseous phase with a solid catalyst. Prof. Mertens de Wilmars discusses methods of studying the influence of various parameters on the evolution of a given reaction under operating conditions. The treatment is general and not devoted to specific reactions but representative reactions are named in the various categories. Synthesis of glycerine is given as an example of a homogeneous liquid phase reaction which may be carried out in piston flow conditions, while the Fischer-Tropsch synthesis is used to exemplify gaseous reactions on a solid catalyst producing an excess of heat. In the latter case an original method is put forward for determining the size of autothermal reactors. The physico-chemical treatment naturally does not lend itself to summary and we can only refer readers to the original for guidance in this field.

Industrie Chimique Belge, 1957, **12**, 1443.

Rapid Weight-Strength Analysis of Pressure Vessels

A SIMPLE method of speeding the weight calculations for pressure vessels has been put forward by R. E. Wong in a recent issue of *Product Engineering* (1957, **28** No. 14, 95). As a starting point, the simple weight-volume ratio formulae for cylinders, spheres and elliptical or spherical heads have been derived. Based on a recommended list of proof pressure stress values, charts have then been constructed derived from these formulae as functions of pressure, capacity and material. The stress level adopted is that producing a volumetric set of not more than 0.1% of total volume, corresponding to a permanent material strain of 0.0005 in./in. for cylinders and 0.0003 in./in. for spheres, and modified by an appropriate safety factor. A sample problem completes the presentation of the method by showing a rapid computation of the weight of a 1000 gallon annealed stainless steel tank of 60 in. diameter with elliptical heads, working at 30 psi. The charts are likely to be of value where a series of computations must be made involving different sizes, pressures and materials wherever space and weight limits must be considered early in the design.

More extensive was the symposium in Ind. Eng. Chem. (Dec. 1957). This included treatments of equipment, safety, design considerations and fundamentals, as well as four articles on specific processes operated at high pressures.

Criticality, a Special Case of Scale Effect

WHEN a sufficient quantity of fissile material such as plutonium −239, uranium −233 or −235 is present under suitable conditions, a fission chain-reaction can be initiated. This may evolve heat and dangerous radiations. In extreme cases, it could cause an explosion. We have even heard that the military use this effect.

However, purely in chemical engineering terms this appears to be a novel factor in design and operation in plants. At the recent symposium on nuclear energy sponsored by the Institution of Chemical Engineers, nuclear criticality formed the subject of an interesting paper by C. M. Nicholls and A. H. C. P. Gillieson. The relevant neutron physics was reviewed as a basis for discussing safe designs of geometrically simple, then more complex, isolated solution systems. At equilibrium, criticality is the condition when the number of neutrons captured and producing fission equals the total of neutrons in the equipment from previous fissions, plus those reflected and those gained from other equipment. In addition to more spectacular effects, an insidious danger to be avoided is a minor incident in which there would be no outward sign of an accident. In such cases, unless

warning instruments were provided, it would be possible for operators to enter unknowingly a dangerous radiation area. The precise form of the size and shape limitation due to this factor is undoubtedly unique. Yet is this true of the principle? As a simple example, it is evident that increase in size of a chemical reactor decreases the ratio of surface area to volume, decreases the surface area for heat dissipation per unit mass and can lead to increased temperatures in the interior. There are certainly chemical reactions in which the criticality concept—including the risk of explosions—has had to be in the mind of designers. Surely, what is truly novel is the much greater danger now involved and the smallness of the quantity leading to nuclear criticality particularly as the concentration of fissile material increases. These considerations make it more difficult when handling active materials to evolve designs which are economic as well as safe. Design thus becomes a struggle—as Prof. Danckwerts commented at the symposium—between designers wanting larger size on economic grounds and criticality experts who are thought to be using excessive factors of safety.

Fitting Branches to Pipes Without Interrupting Fluid Flow

WE recently came across an interesting device for connecting branches on to pipes containing fluid without interrupting the flow. The procedure consists of clamping down a side branch over a ring gasket on to the outside of the pipe to which the fitting is to be made. The side branch is already provided with a valve seat, a "T" piece, plug cock and a gland and also with an extension yoke. Through the gland is passed a drill. The wall of the main tube is then drilled and the drill withdrawn to a position between the plug cock and the gland. Momentary flow of liquid out of the new hole flushes away the drillings into the side-arm. The plug cock is closed. The drill can now be withdrawn completely and the valve plug and stem introduced through the gland. The plug cock is opened, the valve plug pressed down on to the seat and the side branch is now ready for use fitted with a control valve. The source? A paper by Carl Reuther of Mannheim to the 26th Meeting of the Mittelrheinischer Gasindustrieverein in Alsace which was printed in Munich in 1888. The water supply industry uses a modern variant of this ingenious scheme. Has it been "noticed" by the chemical industry?

Determining Particle Size Distribution by Centrifugal Sedimentation

SLURRIES of thorium oxide in aqueous media are under test in U.S.A. for use as blankets of fertile material in two-region breeder reactors. Physical properties which may be used for characterization of thorium oxide or correlated with pumping characteristics, settling rates or stability are of special interest and must be determined. One of these properties which is related to the hydrodynamic behaviour of the slurries, is the size distribution of the particles. In a recently declassified report from the Oak Ridge Laboratory, O. Menis and colleagues report that for particles less than two microns in diameter, difficulties are encountered using gravitational sedimentation methods for this purpose. With decreasing particle size, the period of sedimentation becomes excessively long and the effects of convection currents and the Brownian movement become increasingly important tending to invalidate the test results.

Mr Menis therefore developed a cumulative, centrifugal sedimentation method applicable to determining the particle-size distribution of thorium oxide in the particle-size range of 0.1 to 2.0 microns in diameter. By selection of suitable operating conditions it is possible to accomplish sedimentation in small, cylindrical-shaped cells in 25 minutes or less. Under these selected conditions of sedimentation — detailed in report ORNL-2345 — the particle-size distribution can be obtained from the cumulative sedimentation data by applying either Oden's method of tangential intercepts or a function-plot method. Results by this centrifugal method correlate well with results obtained by different gravitational sedimentation methods for the portion of sample composed of particles greater than two microns in diameter.

Soviet Aluminium Production

WHEN we recently read that a Soviet aluminium plant at Krasnoyarsk would be the largest in the world, the news made us curious about the significance in terms of world production. Thanks to the cooperation of Dr. E. G. West of the Aluminium Development Association we can now set this in perspective. At the end of 1956, expert estimates for annual production of virgin aluminium in the U.S.S.R. varied between 390,000 and 540,000 tons. This would place Russia third among world producers, with the U.S.A. first and Canada next. Western Europe as a whole—France, Western Germany, Italy, Switzerland, Norway and Austria—total together about 500,000 tons and thus equal or exceed the current Russian output. By the end of 1956, estimated world production was 3.5 to 3.7 million short tons, with North America producing over 60% of the total, most of the balance being produced by Western Europe and Russia. It is likely that the world aluminium capacity at the end of 1957 was well over 4.2 million tons. This new plant at Krasnoyarsk with a planned output of up to 400,000 tons ingot per year will greatly alter the world picture. Noteworthy, too, is the report that it will be using alumina produced from nepheline rather than bauxite which is, nevertheless, plentiful in Russia. It is only quite recently that sources of the metal other than bauxite have been used anywhere in the world. Now nepheline is being used in the U.S.S.R., while in the U.S.A. a large scale pilot plant was started up last year using clay.

The Soviet Union is thus a major producer of aluminium and its forward plans appear to be at least as ambitious as those of the U.S.A., Canada and those Western countries interested in aluminium plants in West Africa and elsewhere. Fairly substantial quantities of aluminium have even been imported into the U.K. from the Soviet Union during the past few months.

Using Free Radicals

ROUGHLY a year ago the U.S. National Bureau of Standards undertook a three year programme of basic research on free radicals. The object was to increase fundamental knowledge of the formation, properties and storage of these highly reactive molecular fragments. Ordinarily, free radicals exist only for very short periods in systems such as flames, electric arcs and hot gases. For example, radicals containing only a few atoms, such as methyl or hydroxyl, normally have lives of only a few thousandths of a second. But in the past few years numerous methods have been developed for capturing and storing them mainly at low temperatures. N.B.S. workers

have frozen the products of an electric discharge at a few degrees absolute, capturing some types of free radicals in highly excited states and making it possible to study them including analysing them spectroscopically. This opens a whole new field of low temperature chemical kinetics which, in principle, offers prospects of a very significant effect on industrial chemical processes. Dr. A. M. Bass, Assistant Chief of the Free Radicals Research Section, has informed us—in a note discussing initial indications of this work—that from free radical stabilization processes, it may be possible to synthesize new materials, to improve the yield in the synthesis of materials that have been produced other ways, and perhaps even to provide better control over various industrial processes. However, the work is still at an early stage and the details of the mechanisms by which the results may be achieved have yet to be discovered. Last autumn, a symposium on free radicals was held at the N.B.S., bringing together more than 400 scientists from industrial and university laboratories in U.S.A., Gerat Britain, France, Canada and Italy.

Record of the Nationalised Industries

FOOD for critical thought is in the Labour Party's pamphlet-apologia for the nationalised industries entitled "Success Story". In the main it fulfils the claim of the foreword that an emotional approach has been avoided. Facts and figures are presented for the group of nationally run industries—civil aviation, coal, transport, electricity, gas—while atomic energy is discussed in the conclusion. A strong case is made for the thesis that prices in these industries have increased less than the overall movement of prices and that they are more efficient than they were, as judged by several yardsticks of efficiency. Apart from the possibility that data have been tendentiously chosen, the only touch of conventional pamphleteering lies in the quotations from Conservative spokesmen. While some are quoted from the period up to 1951 forecasting economic disaster due to nationalising, their counterparts a few years later are cited in pæans of praise for the performance of the industries taken over. The pamphlet stays strictly within the limits of examining the record and makes no overt proposals for future claimants for these benefits.

What Happens Inside Sealed Hollow Plungers of Water Pumps?

A MECHANIC drilling a sealed hollow plunger of a water pump was seriously injured by a large flame which shot out when he drilled through the plunger wall. Reporting this accident John B. Murphy in "Power" (Nov. 1957, p. 122) said that he afterwards drilled a second plunger with adequate precautions and again found this to contain flammable gas at high pressure. The gas burnt with a clear blue flame. There is no reference to chemical analysis of the gas in this account and, in fact, no report of any serious attempt to investigate the gas. The article serves the sole but useful purpose of warning others about the risk so that they can take due precautions. Mr. H. F. Cronin, Chief Engineer of the Metropolitan Water Board, informs us that this trouble has never been encountered by his Board. On their vertical triple expansion engines the pump rams are of cast iron and have open tops so that there is no possibility of any gases collecting inside them. It would be interesting to know if these difficulties have arisen elsewhere in Britain and whether the source of the pressure build-up has been investigated. Is the problem peculiar to plungers or is it liable to arise in stationary hollow metal fittings which are sealed by welding?

Crystallisation of Potassium Chloride from the Crude Mineral

THE basic process involved in recovering potassium chloride from the natural salts such as sylvine or rock salt is apparently simple. The salts are crushed and a hot concentrated solution of them is prepared in suitable plant. The solution is separated from insoluble material and the potassium salt crystallised out by cooling. After heating the mother liquor is used again for dissolving fresh raw salt. Yet there is much to be learned about detailed control of the technique. In a recent article* H. Autenrieth and colleagues discuss the theoretical basis and the development of crystallisation technique. Dr. Autenrieth then continues by reporting experiments which have been carried out to produce a coarse crystal product using multi-stage vacuum cooling plants with evaporators fitted with agitators. The influence of the rate of cooling, rate of agitation, seeding crystal recirculation and sediment present in the liquor are all described with particular reference to the quality of the crystal and the possibility of blocking the seed liberating effect of the suspension. Included in the investigation was also a study of the possibility of increasing crystal size by adding small quantities of surface active agents to the hot solution.

* *Chemie-Ingenieur-Technik*, 1957, **29**, 709.

Packed Glands for High Pressure

THE problem of effecting a fluid seal between surfaces having relative motion is almost as old as engineering itself and in many instances satisfactory solutions have been evolved. Yet there is so far no generally accepted basis of design. In a paper presented to the Institution of Mechanical Engineers, J. L. Thomson now puts forward a theory of operation for packed glands as a basis for design and further research. Prof. Thomson points out that the sealing action of a gland is usually supposed to be brought about by the initial tightening. This may be true at low pressures, but at high pressures the sealing action is automatic, being brought about by the forces resulting from the pressure drop across the packing elements, the effect being cumulative. Each packing element constitutes an annular piston across which there is a pressure difference and, in addition, each element supports those above it and the forces on them. Squeezed by this axial force P, the packing spreads laterally, exerting a sealing force Q on the rod and on the stuffing box wall. To a first approximation one can write

$$Q = KP \text{ where } K \leq 1$$

If the pressure gradient produced is proportional to Q and if this produces a corresponding increase in the axial force P, then it follows that

$$Q = A\,(dP/dL) \text{ where A is a constant} \geq 1,$$

It will be apparent that P will increase exponentially, that is

$$P/P_o = e^{KL/A}$$

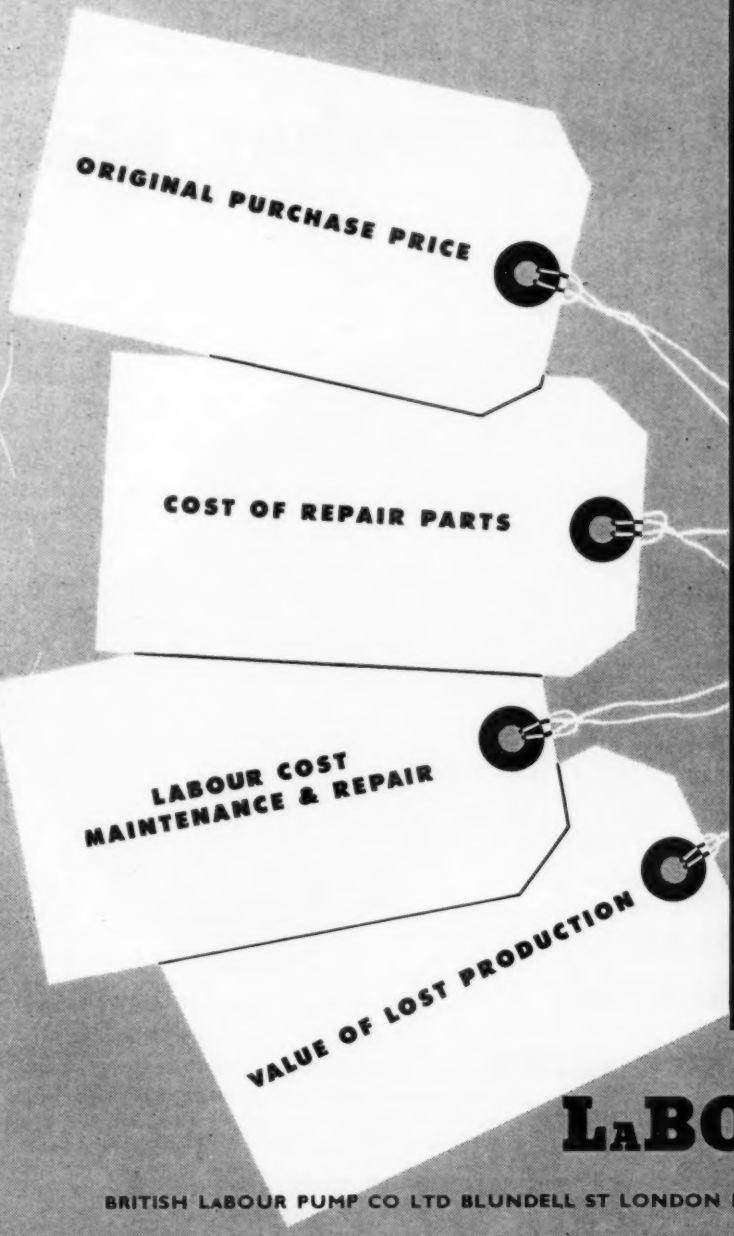
Hence the packed length required for a given pressure drop ($P_{max} - P_{min}$) equal to ($P - P_o$) will be

$$L = A/K \log_e P/P_o$$

Plotting, using a logarithmic scale for P, yields straight lines from which it can be seen that the packed length required for a pressure of 1000 lb/in² is not 10 times, but only one and a half times that for 100 lb/in².

After this introduction the paper goes on to discuss friction, alignment and leakage problems.

HOW MANY PRICE TAGS ON A CHEMICAL PUMP?



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A HEYWOOD PUBLICATION
British Chemical Engineering

Computers for Design and Research

WITHIN the past decade electronic engineering has developed machines with an almost unlimited power to duplicate and amplify man's senses; devices which can match and sometimes surpass many of his natural abilities. Such electronic devices, are the computers which can memorise and recall information, which can schedule and control industrial processes and which can perform involved and tedious calculations within a minute fraction of the time taken by human effort. The value of computers to chemical engineers has been demonstrated by the mass of published examples of its use for design calculations, many of these being aimed at finding optimum designs; often these are operations which could not be possibly achieved economically without their aid.

Many a problem in chemical engineering—some might say unfortunately—has to be expressed mathematically in the form of total or partial differential equations and with a set of boundary conditions. If these conditions are a simple separation of variables, Laplace transformation or other methods may help to solve the problem. If the boundary conditions are complex such an approach cannot be used and it is necessary instead to resort to other methods including numerical ones, of which the "Relaxation" method is typical. In calculations of this kind the digital computer comes into its own and problems concerned with the velocity distribution in pipe flow and exchangers have been solved by this technique.

Some idea of the scope of computer techniques was brought out in a recent paper by R. W. H. Sargent.[1] Precision of design (given reliable physical data), accurate estimation of costs and plant performance, reduced margins in design security, are some of the benefits which are offered by computer-aided calculations. The examples given by Sargent on plate-to-plate distillation column calculations, on the design and performance of multi-channel heat exchangers and on regenerators show how valuable a tool the computer is.

Although the digital computer is the better known, analogue machines also have a special part to play as the recently described solution of a cooler-condenser design problem shows.[2] This kind of problem, which requires a process of continuous integration, is well suited to solution by an analogue machine. The method has been used also for calculating the number of transfer units required by a packed column; clearly, it has other potential applications

The influence of computers upon chemical engineering design is, therefore, evident, but how their use is likely to effect experimental methods is not so clear. According to one developing school of thought, there will be a return to the simplified experiment whose purpose will be to determine a single dependent variable in a system; a decline in the well-established experiment which differs only in size from the full-scale counterpart is expected.

The manner of studying material transfer in packed beds provides an example of this established procedure. It consists of formulating the appropriate differential equations, designing experiments closely resembling the final application and seeking values for the fundamental constants through a close study of the experimental results, in this case the "break-through" curves. It is an approach which has yielded conflicting results and it suffers from at least one serious disadvantage. Contributing to the process of mass transfer are not only solid and fluid diffusion but also axial diffusion; but if an attempt is made to take the latter into account it is impossible to solve the differential equations. Similar remarks can be directed to the method of analysing heat and mass transfer in catalytic converters. With advantage, the analytical approach could be replaced by simple experiments devised in this case to measure singly solid diffusivities, fluid-phase transfer coefficients and axial-diffusion coefficients without transfer and in the absence of other effects. From these experiments it would be possible to obtain values of the basic constants and their dependence upon flow rates, temperature, pressure and so on. The synthesising power of the computer can then be brought into play by feeding to it the equations and the values of the basic parameters. The machine can then tell us what happens in practice as accurately as we could measure and with far greater speed.

So rapid has the development of computers been that the appreciation of what they can do is far greater than the knowledge of how to use them. As well as the task of formulating mathematically a particular process there is the actual programming of information to be fed to the machine; there is also a choice of computer to be made. The small computer can be the more easily programmed, but the large machine compensates for this because it offers a cheaper solution. There are occasions, too, when the greater economy lies in the simultaneous use of two kinds of computer. For this economic advantage to be realised, computer routines need to be generalised for the more frequently occurring engineering problems.

But though computers are freeing the energies of engineers and research workers from tedious routine, there should not be a neglect of other means of solving engineering problems; graphical methods have an important place in the armoury of the chemical engineer, especially with diffusional processes, and there is still a real need for more rapid procedures than some of those in use at present. A noteworthy example of a development in this direction was described recently by R. J. Hengstebeck,[2] who showed how to avoid plate-to-plate calculations for the type of multi-component distillation where two feeds enter and one sidestream leaves a column. There can be little doubt that, great though the influence automatic computer techniques upon engineering have been, it will be far surpassed in the future.

[1] Paper presented at meeting of Low Temperature Group of Phys. Soc. and Inst. Chem. Eng., November 26, 1957.
[2] Papers given to symposium on Chemical Engineering Data and Calculation Methods, June 9 to 12, 1957. Amer. Inst. Chem. Eng.

661.56

NITRIC ACID PRODUCTION

The history of nitric acid manufacture and its chemistry is reviewed briefly and the latest developments in the field are explained in a description of a modern plant

by W. FLETCHER, F.R.I.C., and N. W. ROBERTS, M.A., F.R.I.C.

THE history of the manufacture of nitric acid splendidly exemplifies the response of the inventive spirit to the interplay of political and economic forces, while the design of modern plants demonstrates the value of applying the principles of pure chemistry in a chemical engineering achievement. The economic importance of nitric acid has hitherto varied as the danger of war has advanced or receded. Only recently, with the technical solution of the problems attending the use of ammonium nitrate as a fertiliser, has a measure of stability been introduced into the market for nitric acid.

Nitrates, and in later years nitro-compounds, have always formed the basis of explosives. Napoleon's career was based on the systematic spoliation of the dung-heaps of France for nitre, and a large share of the blame for the famines which beset France at that time may be laid at the door of this policy. Many of the technological advances have been made under the threat or stress of war, although the first synthesis was made with no such threat in mind.

Until the early years of the twentieth century nitric acid

Mr. Fletcher, *who has been a project manager with C.J.B. Ltd. since 1955, studied chemistry and chemical engineering at the Technical College, Huddersfield. After service with the Ministry of Supply during the war, he worked with Organon Laboratories Ltd. until 1951, when he joined The Midland Tar Distillers Co., working first as a plant superintendent and later as a senior chemical engineer.* **Mr. Roberts**, *who has been in charge of chemical engineering development with C.J.B. Ltd. since 1955, studied chemistry at Oxford and has previously been employed by Fisons Ltd., British Oxygen Co. and The U.K.A.E.A.*

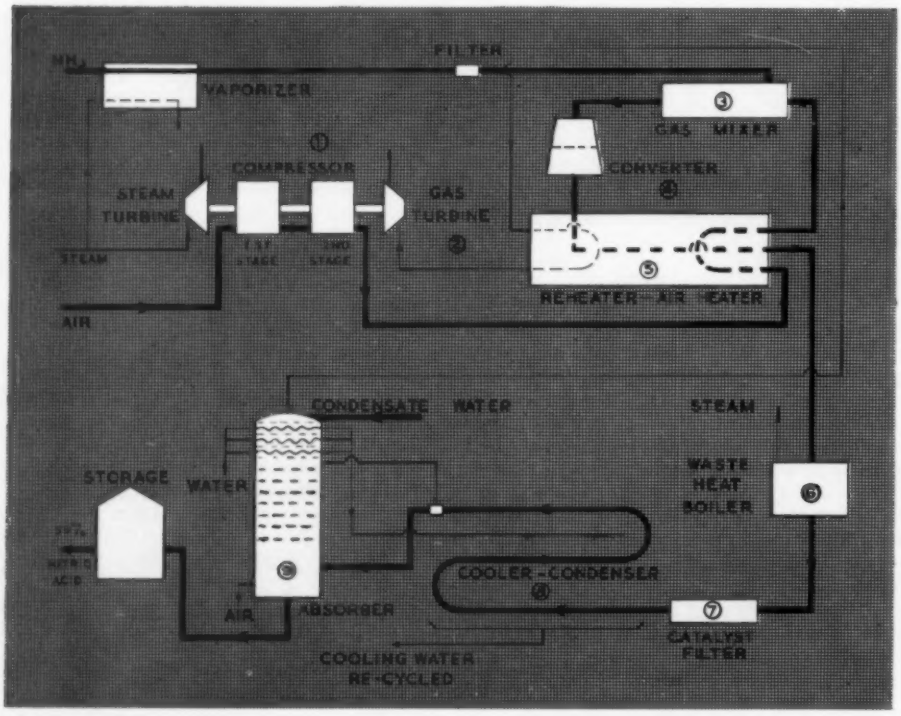

Fig. 1. Flowsheet of modern nitric acid plant using pressure oxidation.

was an expensive chemical, made by the action of sulphuric acid on Chile saltpetre. The revolution began in the first decade of this century when Birkeland and Eyde started the manufacture of synthetic nitrates in Norway. With generous reserves of water power and little else in the way of natural resources, they created an exportable product. They used the fact that at high temperatures the nitrogen and oxygen of the air will combine by passing air through an electric arc which was drawn into a disc by magnetic forces. If the air were then allowed to cool slowly, the oxides dissociated again into their elements, but by a rapid quenching process it was possible to produce a gas containing about 2% of nitric oxide. On cooling, this combined with more oxygen to form nitrogen dioxide which could be absorbed in water to make a weak nitric acid. The process continued in successful commercial operation until the development of synthetic ammonia, as a cheaper source of fixed nitrogen made it no longer profitable.

The manufacture of synthetic ammonia was developed in Germany before the First World War and the German scientists rapidly turned their attention to its atmospheric oxidation to make nitric acid. The successful solution of this problem was a major factor in enabling the Central Powers to carry on the war in face of the Allied blockade, which prevented access to Chilean nitrates. The atmospheric oxidation process has been developed by the application of new materials and techniques until it has no serious competitor.

The raw materials required for nitric acid production are ammonia, air and water. Where long transportation distances are involved, the low molecular weight of ammonia (containing 85% nitrogen) makes it much more economical to transport than nitric acid. Since ammonia manufacture tends to be centralised in large plants in areas of low fuel cost, it is more convenient to transport liquid ammonia to oxidation plants located in the consuming areas than to complete all the stages of fertiliser manufacture in the central plants. When rail transport is used, one mild-steel ammonia tank carries the equivalent of six stainless-steel tanks containing nitric acid.

The reaction between ammonia and the oxygen of the air is carried out over a platinum-rhodium gauze catalyst at a temperature around 1700°F. Three reactions are involved. The main one is the following:

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O \text{ (vap.)}; \quad \ldots . (1)$$
$$\triangle H \text{ (at } 298°C) = -216{,}000 \text{ cal.}$$

There is a possibility of two side-reactions occurring, namely:

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O \text{ (vap.)}; \quad \ldots . (2)$$
$$\triangle H \text{ (at } 298°C) = -302{,}000 \text{ cal.}$$

$$4NH_3 + 6NO \longrightarrow 5N_2 + 6H_2O \text{ (vap.)}; \quad \ldots . (3)$$
$$\triangle H \text{ (at } 298°C) = -432{,}000 \text{ cal.}$$

To prevent these side-reactions from taking place, it is necessary to maintain the catalyst at a high temperature. Comparison of the heats of reaction shows that an increase in temperature will favour the main reaction at the expense of the other two.

After disposing of the sensible heat of the reaction gases, the second series of reactions are carried out.

$$2NO + O_2 \longrightarrow 2NO_2 \quad \ldots . (4)$$
$$\triangle H \text{ (298°C)} = -27{,}100 \text{ cal.}$$

$$3NO_2 + H_2O \text{ (liq.)} \longrightarrow 2HNO_3 \text{ (liq.)} + NO \quad \ldots . (5)$$
$$\triangle H \text{ (at } 298°C) = -32{,}200$$

Both of these reactions involve a contraction in volume, and are therefore assisted by the use of high pressures. The absorption of the oxides of nitrogen from the gas stream nevertheless presents a difficult problem, since reaction (5) liberates nitric oxide which has to be reoxidised in the gas phase.

Although the small increase in volume shown in reaction (1) would suggest that pressure would have an unfavour-

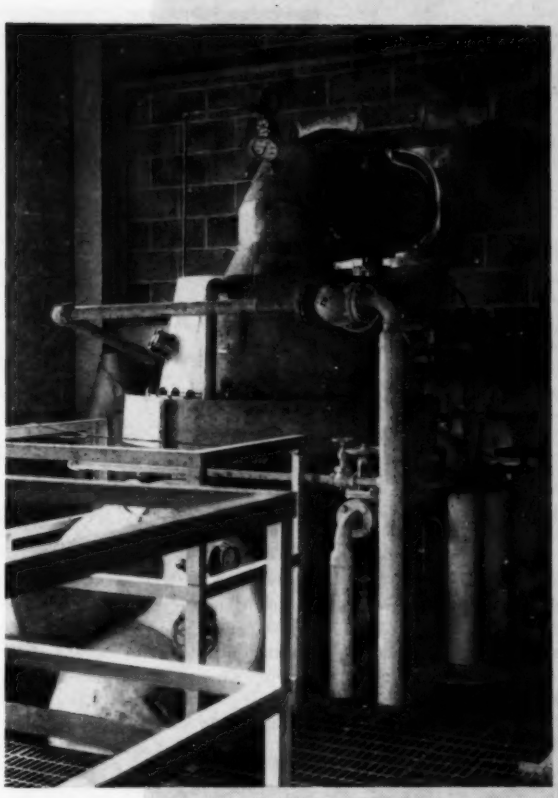

Fig. 2. Converter showing re-heater comprising two heat exchangers. The stainless-steel catalyst chamber contains platinum-rhodium alloy gauze.

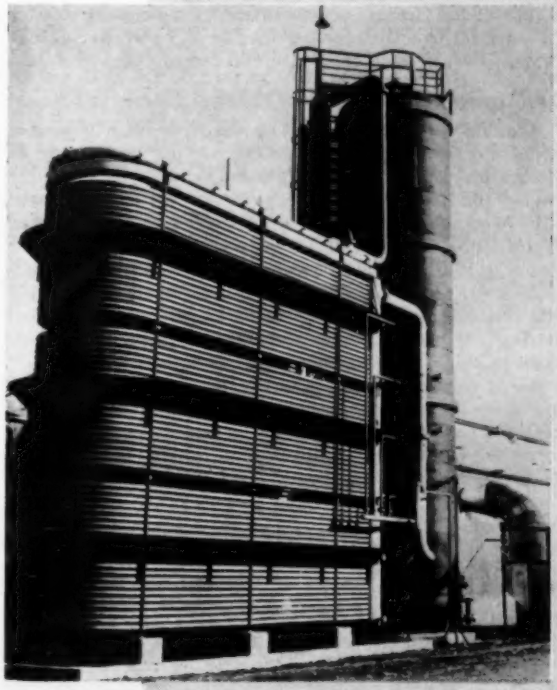

Fig. 3. Column condenser and absorption column. (Photos: Chemical & Industrial Corporation and Allied Chemical & Dye Corporation.)

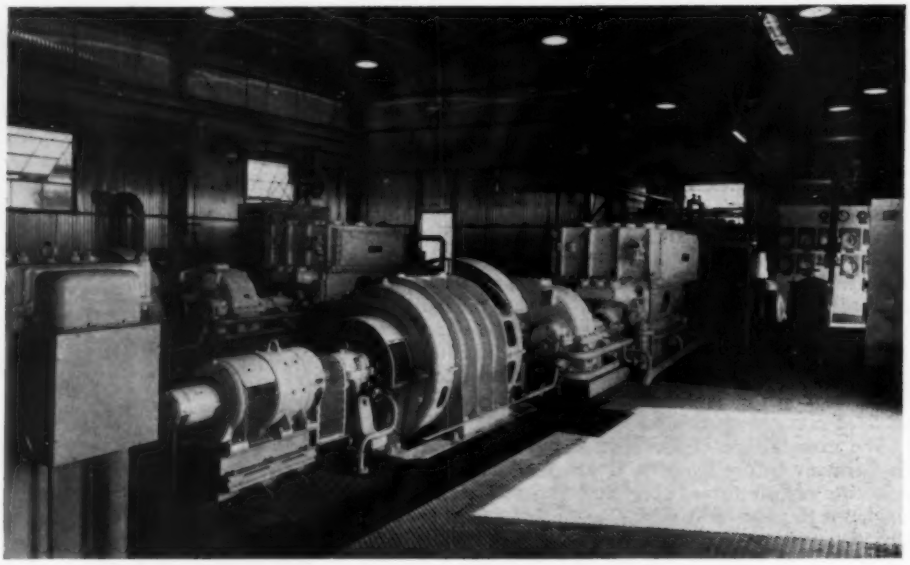

Fig. 4. Brown Boveri compressor expander in Compressor House. By courtesy of Chemical & Industrial Corporation and Union Chemical Company.

able effect on the forward reaction, it is found that the equilibrium is not materially affected by pressure. On the other hand, the use of high pressures allows of a correspondingly high space velocity, which results in smaller equipment and this advantage far outweighs the minor equilibrium effects. The contact time is of the order of 3×10^{-4} seconds.

The advantages of pressure operation can equally well be obtained by the use of 98% oxygen as an oxidant instead of air. Indeed, several plants have been erected on this principle (Bamag). However, the development of the pressure oxidation process has brought equipment costs to such a low level that the further advantage of using pure oxygen under pressure is outweighed by the cost of making the oxygen. This situation persists despite the advances in tonnage oxygen technology made in recent years.

Description of a Modern Plant

A modern plant may now be described with reference to the flowsheet (Fig. 1). The engineering description of the various items relates to a plant capacity of 150 tons/day of 100% nitric acid, produced at 65% concentration. Air is drawn from the atmosphere at the rate of 15,000 scfm, and compressed in a centrifugal compressor to 120 psig. Part of the power required to drive the compressor (1) is supplied by an expander turbine (2) using the pressure energy of the waste gas (mainly nitrogen) leaving the plant; the remainder is supplied either by a steam turbine or by an electric motor.

Air is compressed and led to the gas mixer (3) in which the ammonia is introduced to the gas stream. Special precautions have to be taken in the design of this equipment to ensure by efficient mixing that explosive concentrations are not reached at any point. It is at this stage, too, that foreign matter, which may be present either in the air or in the ammonia stream, is removed to prevent it entering from the catalyst chamber or converter (4).

The converter is a stainless-steel vessel designed to support the 315 oz. of platinum-rhodium alloy gauze, and to suit the pressure and temperature conditions. An electric igniter is provided together with a temperature recorder-controller connected to an excess temperature shut-down device. Sight glasses permit visual inspection of the catalyst during operation as well as allowing the use of a photoelectric flame monitor, which gives warning of maloperation of the reaction.

The hot gases leaving the converter at a temperature of 1700°F pass into the gas reheater-air heater (5). Two heat exchangers of different duty are here built into a single shell, through which pass the products of the oxidation reaction; the latter first pass over the 98 U-tubes of the gas heater bundle, and then the tubes of the air heater which is of similar construction. The former bundle serves to increase the energy content of the waste gas leaving the absorber before expansion in the power recovery gas turbine, while the latter provides preheat for the air-ammonia mixture before it enters the converter. The amount of preheat is controlled by means of a by-pass valve. The heat exchanger is built of stainless steel.

Then follows the waste-heat boiler (6), which is a fire-tube type horizontal boiler generating 6000 lb./hr of steam at 150 psig. The pressure at which the steam is generated can be varied according to the standards of the factory in which the plant is installed. The gases then pass through the platinum filter (7) which is packed with glass wool. This traps any particles of platinum thrown off by the catalyst gauze and carried in the gas stream. From time to time the filter is removed and the platinum recovered. The gases complete their cooling to near-atmospheric temperatures in the cooler-condenser (8). This is a cascade-type evaporating cooler in the form of banks of horizontal tubes of sufficient cross-sectional area to give an optimum pressure drop, and providing adequate oxidation space and drainage capacity for the removal of nitric acid. It is made of stainless steel. The nitric acid produced is rather dilute and must be fed into the absorption column for strengthening.

In the absorption column (9) the gases pass through 36 bubble plates, the spaces between which are designed to allow adequate volume for the nitric oxide which is evolved when nitrogen dioxide is absorbed in water. The nitric acid emerging at the bottom of such a column is saturated with nitrogen dioxide at the partial pressure of entry and is therefore dark brown. To remove this, the acid is bleached by countercurrent contact with air in a further series of four bubble plates. For convenience in manufacture, both bleaching and absorption columns are fabricated in a single shell of diameter 8 ft and height 50 ft. Between the bubble plates many cooling coils are included to remove the heat of absorption and to transfer it to the cooling water. The unit construction allows the column to be free-standing without a steel framework.

The gas leaving the absorption column is substantially nitrogen but contains about 0.3% of oxides of nitrogen which may nevertheless be objectionable as atmospheric effluent. They may be completely removed after the gas has been passed through the gas reheater by a partial combustion technique utilising natural or refinery gas. This refinement, which is not shown on the flowsheet, enables the manufacturer to have a completely harmless effluent from his stock.

The interconnecting pipework of the plant is made of stainless steel for both the gas and the liquid lines, including the transfer of the product to storage. Full instrumentation is provided, including all necessary alarms, indicators, rupture discs, and other safety devices which reduce the possibility of damage to the catalyst to negligible proportions and avoid off-stream time losses.

The main economy of the pressure oxidation process may be illustrated by the fact that an equivalent atmospheric pressure oxidation plant would require seven absorption columns of greater diameter to cope with the fifty-fold decrease in reaction rate. Such towers alone would cost twice the price of a complete pressure oxidation plant.

While the atmospheric pressure oxidation process offered a great decrease in production costs over the older methods of manufacturing nitric acid, the pressure conversion and absorption technique has resulted in further substantial economies. In one case where both processes were operated side by side in the same factory the following advantages were found to exist in favour of the pressure oxidation process. The new plant costs half per ton installed capacity, occupies one-twelfth the factory space, and uses one-third of the man-power (including both operating and maintenance staff) of the older one.

The capital cost of a pressure oxidation unit of 200 tons/day capacity, excluding off-site facilities, storage and piping would at present prices amount to about £540,000. A unit of 50 tons/day would cost approximately half this figure. The operating material requirements of a number of plants of different types are tabulated below. Quantities in all cases relate to a ton (2240 lb.) of 100% nitric acid.

	(1)	(2)	(3)	(4)	(5)
Liquid ammonia, lb.	655	656	656	644	650
Steam consumed, lb.	440	2500	440	—	—
Cooling water gl.	33,000	33,000	25,000	—	—
Electricity, kWh	160	2	160	300	180
Condensate, gal.	100	—	73	—	110
Steam produced, lb.	1300	—	—	—	—
Platinum loss, oz.	0.0028	—	—	0.013	0.006

Of the plants referred to in the table, (1) (3) and (5) are plants which use turbine power recovery, the remainder of the power required by the air compressor being supplied by an electric motor. (2) uses a steam turbine to assist the gas turbine, while (4) uses a reciprocating expander to recover the power; the lower efficiency is clearly demonstrated in the higher power consumption.

The higher efficiency recorded by turbine expanders is not so much due to their higher mechanical efficiency, which is in any case marginal, but to the fact that the inlet temperature with a turbine expander can be 900°F, compared with 500°F which is the practicable limit with reciprocating machines. The higher temperature gives about 50% more available energy in the gas.

Thanks are due to Chemical & Industrial International Ltd. for their helpful co-operation in the preparation of this article and in particular for the provision of photographs. In recent years they have designed and built 90% of the nitric acid plants erected in the U.S., and the capacity which they have provided now aggregates over 4000 tons a day.

Plant for Paint Manufacture

OF the twenty manufacturers of plant and instruments who will exhibit at the tenth Technical Exhibition of the Oil and Colour Chemists' Association in the Royal Horticultural Society's New Hall, Greatcoat Street, London, S.W.1, from March 11 to 13, a number have announced the new products they will be featuring. Among these are VICKERS ARMSTRONG (ENGINEERS) LTD., Broadway, London, S.W.1 (Stand 62), who will show their newly-patented Solventite device which has been designed for condensing vaporised materials driven off from high-speed stone mills and, at the same time, for lowering the milling temperature. The equipment will be used with the company's new Ultramill, of which details will be available on the stand. A development of the Ultramix high-speed mixing machine in the form of a new type of turbine of patented design will also be shown. The principle employed is that of subjecting a portion of the material passing through the turbine to very intense shear and agitation in parallel with the main stream. A high degree of dispersion is obtained, the makers say, while adequate turn-over of the batch is maintained.

KESTNER EVAPORATOR & ENGINEERING CO. LTD., 5 Grosvenor Gardens, London, S.W.1 (Stand 74), will show a complete prototype model of a plant incorporating their patent "hot coil" gas-firing system which, they say, offers a large heating surface to material being processed and eliminates excessively hot points of contact. Another new development to be shown is their Isoductive electrical heating system for vessels or pipe-lines. It can be arranged for use in flameproof areas. New among the company's smaller equipment will be a flameproof portable stirrer.

L. A. MITCHELL LTD., 37 Peter Street, Manchester, 2 (Stand 76), will make a special display of their 10-gallon pilot-scale resin plant, the heating efficiency of which they have raised so that considerable saving can be achieved by the use of induction heating. Also to be shown for the first time is a range of laboratory mixers and a slow mixer fitted with turbo-type impellers. A new variable-speed Steel-Shaw mixing machine will be available for inspection on the stand of STEELE & COWLISHAW LTD., Cooper Street, Hanley, Stoke-on-Trent (Stand 45). Technical staff will attend to provide information on the company's range of ball and pebble, porcelain, pot and kinetic dispersion mills. The production version of the Premier dispersion mill, model 6000, the prototype of which was shown at last year's exhibition, will be displayed on the stand of PREMIER COLLOID MILLS LTD., Hersham Trading Estate, Walton-on-Thames, Surrey (Stand 70). Although, as in previous years, WINKWORTH MACHINERY LTD., 65 High Street, Staines, Middlesex (Stand 41), will show laboratory machines for convenience of exhibition—their laboratory mixer will be the main exhibit—full details will also be available of larger size mixers and blenders which are made to specific requirements.

A range of heat-transfer media suitable for heat-transfer operations in the surface-coating industry will be featured by MONSANTO CHEMICALS LTD., 10 Victoria Street, London, S.W.1 (Stand 21). They will include Aroclor 1248, diphenyl and a range of aryl silicates. Visitors to the stand of METAL PROPELLERS LTD., 74 Purley Way, Croydon (Stand 42), will be able to see some of the latest data obtained from pilot-plant development work carried out on the company's Thermagrid tubular distillation tray.

A note of new developments in plant and protective coatings for plant seen at the exhibition will be published in the May issue of *British Chemical Engineering*.

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PROPOSED LIQUID-EXTRACTION DEVICE USING A CENTRIFUGAL FIELD

A good deal of work has been done in the chemical Engineering Division at the Atomic Energy Research Establishment, Harwell, on liquid-liquid extraction. Attention has been directed to the development of contacting devices as well as to the theoretical study of the operation. In the course of this work, Dr. S. G. Bauer, who was then at the Establishment, suggested that a substantial benefit might be obtained from an application of a centrifugal field to a counter-current exchange device. To stimulate interest in this approach, he wrote the report which we reproduce below

by S. G. BAUER, Ph.D.(Cambridge)

IN a liquid-extraction counterflow column the size of drops of the dispersed phase has a lower limit, set by the velocity at which such drops will travel through the continuous phase under the forces of buoyancy. Hence for practical throughputs of the column not much can be done to increase the available surface area per unit volume, though the time of contact can be increased for a given length of column and drop size by introducing packings.

Columns have been built in which the drop sizes are drastically reduced by stirring devices, but these preclude effective counterflow and the column has to be designed as a succession of mixing and separating stages, thereby losing much of the potential advantage of drop size reduction. Very small drops of small density difference from the continuous phase can, however, be induced to move at practical velocities in a centrifugal field. It is suggested, therefore, that a stationary column should be replaced by the rotating device which provides a centrifugal field and at the same time a stirring action required to comminute the droplets of solvent. A true counter-flow is possible in such a system by virtue of the fact that the turbulence necessary for breaking up droplets is substantially confined to peripheral planes by the rotation of the system.

By way of example, some rather arbitrary figures are worked out below. For the purpose of comparison, let us assume that we wish to duplicate the performance of a conventional packed column with the rotary device and assume the following data for the column. The column is designed to operate on hexone-water with a density difference $\Delta\rho=0.2$. It is 6 m. (20 ft) long, has a mean drop size $\bar{d}=2.6$ mm. and a mean rising velocity of drops $r=$ 750 ft/hr$=6.35$ cm./sec. It is further assumed that the product of surface area of the single droplets exposed and the time of exposure determines the performance of the column.

The mean transit time t:

$$t = \frac{600}{6.35} = 94.5 \text{ sec.}$$

The drop surface area per unit volume s:

$$s = \frac{34\,\pi\,a^2}{4\,\pi\,a^3} = \frac{3}{a} = \frac{3}{0.13} = 23.1 \text{ cm}^2\text{/cc.}$$

Hence

$$st = 94.5\ 23.1 = 2190 \text{ cm.}^2 \text{ sec./cc.}$$

where a is the radius of the drop.

The drag of a sphere in a viscous liquid is

$$D = 6\ \pi\eta\ a\ v \text{ (Stokes law)}$$

where D is the drag in dynes;
a the radius in cm.;
η the viscosity in poises
v the velocity in cm./sec.

Equating the drag with the buoyancy

$$D = \frac{4\pi}{3}\,a^3\ \Delta\rho\ g$$

we get

$$v = \frac{2a^2\ \Delta\rho\ 981}{9\ \eta} = 218\,\frac{a^2\ \Delta\rho}{\eta} \text{ per } g \text{ acceleration}$$

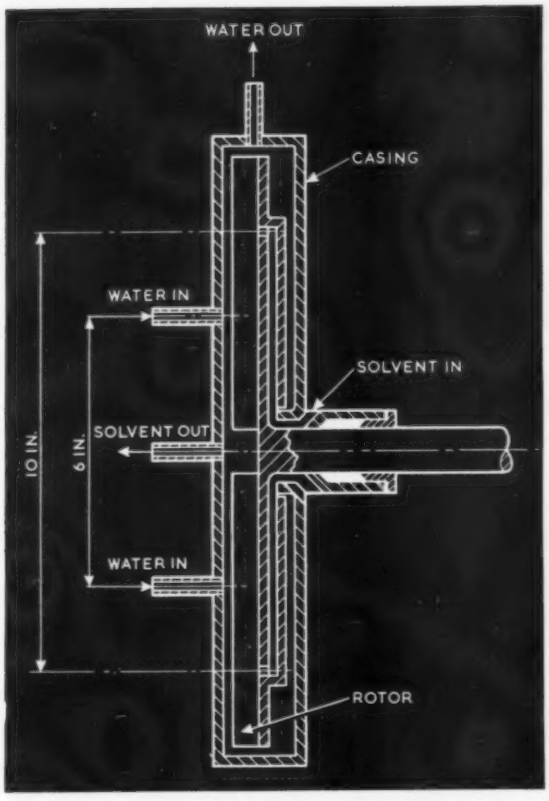
with p the acceleration in units of g.

$$\Delta\rho = 0.2$$
$$\eta = 0.01$$
$$v = 4.36\ 10^3\ a^2\ p$$

and with l the length of countercurrent path

$$ts = \frac{3\,l}{va} = \frac{3\,l}{4.36\ 10^3\ a^3\ p} = \frac{1}{1.45\ 10^3} \cdot \frac{l}{a^3\ p}$$

Dr. S. G. Bauer, *who gained an engineering degree at the Eidgenössische Technische Hochschule, Zurich, in* 1933, *and his Ph.D. at Cambridge in* 1937, *joined the original atomic energy team at Cavendish Laboratory in* 1941. *He served with the U.K. Canadian joint atomic energy team in Canada* 1943-1946, *and from* 1946-1954 *in the engineering and chemical engineering divisions at Harwell. In* 1954 *he joined Rolls-Royce to establish their nuclear team.*



A diagrammatic sketch of a possible layout for a centrifugal liquid-liquid extraction unit.

$$\text{or } a^3 = \frac{1}{1.45\ 10^3} \cdot \frac{l}{p\ t\ s}$$

The equation given above establishes the drop radius to be achieved by mixing to give the desired time x area.

Taking for example:

$$l = 5 \text{ cm.}$$
$$p = 250\ g$$
$$ts = 2190\ \frac{\text{cm.}^3 \text{ sec.}}{\text{cc.}} \text{ (equivalent to column)}$$
$$\therefore a^3 = \frac{5}{1.45\ 10^3\ 250\ 2190} = \frac{1}{159\ 10^6}$$
$$a = \frac{1}{543} \text{ cm.} = 1.84\ 10^{-3} \text{ cm.}$$

drop diameter $d = 36.8\mu$

There should be no particular difficulty in breaking the solvent into drops of this size by induced turbulence.

Some estimate of the probable throughput of such a centrifugal device is necessary. The velocity of the droplets

$$v = 4.36\ 10^2\ a^2\ p$$

which with the above results give:

$$v = 3.67 \text{ cm./sec.}$$

Assuming a hold-up of 30% which should be well within flooding limits, the solvent throughput becomes 1.1 cc./cm.^{2} sec. on the effective cross-sectional area, which is not radically different from conventional columns. A path length of 5 cm. in the radial direction should, however, be equivalent to 20 ft of column.

Assuming the device were to rotate at 1500 rpm and we wish to have a mean centrifugal acceleration of 250 g,

$$\omega = \frac{2\ \pi\ 1500}{60} = 157$$
$$r = \frac{\omega^2}{250\ 981} = 10 \text{ cm.}$$

i.e., the countercurrent path would take up the part of the rotor lying between 15 cm. and 25 cm. diameter (6-in. and 10-in. diameter.)

The diagrammatic sketch shows a possible layout, though many variations can be envisaged. The rotor can very easily be arranged to provide the pressure necessary for the solvent feed if this should prove a difficulty.

Copper Alloys for Corrosion Resistance*

CORROSION of copper and its various alloys may be uniform and, therefore, predictable, or it may be of a highly localised and more damaging character. Dezincification, pitting, impingement, stress corrosion and corrosion fatigue are examples of this latter kind of attack.

The dissolution of a Zn-Cu alloy in a reagent and the redeposition of porous copper from it is known as dezincification. It is favoured by stagnant conditions and can occur either in "layer" or "plug" form depending upon whether the Zn content of the alloy is high (e.g., Muntz metal) or low (brasses). Cu alloys of 85% and alloys of lesser Cu content containing As, Sb or P are not prone to this kind of attack.

Pitting corrosion is likely to take place when foreign solid matter settles upon a metallic surface in contact with an aqueous solution. In such cases, if there is a deficiency of oxygen beneath the deposited matter compared with surrounding areas, oxygen concentration cells will form with the anodes at the areas covered by the deposits.

The removal of a normally protective film of corrosion product by a high-velocity liquid stream sets up impingement attack.

Stress corrosion occurs when stresses are present in a structure in contact with a corrosive medium. For it to take place, the stress must exceed a certain minimum value for the alloy and medium. It occurs often in the presence of moist ammoniacal vapours, salts of Hg and liquid metals. Admiralty brass condenser tubes with a slight bending stress are liable to fail through this form of attack if the feed vapour contains small amounts of CO_2, air or ammonia.

The combined action of corrosion and fatigue leads to a more severe attack than either agency separately. It sometimes occurs when vibrations of heat-exchanger tubes have sufficient amplitude for fatigue to enter the picture. 70-30 Cu-Ni has good resistance to fatigue as well as to corrosion.

Some of these forms of attack can be successfully resisted by means of clad materials composed of copper alloys. In heat exchangers, tube plates can be constructed of clad materials to avoid the expense and complication of double tube plates. In ammonia refrigeration plants, steel-copper duplex tubes can be used for the heat-exchanger equipment, the copper for resisting the action of water or brine and the steel for the ammonia. Cooling coils for batch reactors have been constructed from tubing with 70-30 Cu-Ni interior and an 18-8 exterior. In one particular case a coil of this kind replaced one of 18-8 which had failed through stress corrosion in the presence of brine. Again, duplex tubing with either Cu or 19-10 Cu-Ni exteriors and an 18-8 interior resists pitting attack.

* Abstracted from a paper of this title given by R. V. L. HALL at the Symposium on Materials of Construction, A.I.Ch.E., Chicago, December 8 to 11, 1957.

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A NEW LOOK AT LITHIUM METAL

Unexpectedly varied are the chemical and process possibilities of lithium. The author reviews many properties of this reactive metal and some of the newer applications

by MARSHALL SITTIG

LITHIUM is one of the most reactive metals, but it is appreciably less reactive than sodium. The physical properties of the metal, which make it attractive for many of its present and potential uses, are summarised in Table 1. While this table appears to be a relatively straightforward listing, it should be pointed out that the values cited are the best available values today, and that there are many values in the literature which disagree with them.

This disagreement between various investigators on physical property values for lithium is probably one of the outstanding characteristics of the lithium literature. Incidentally (and unfortunately), it seems to be equally true for many lithium compounds. This is probably due in part to the doubtful purity of samples of material worked with some years ago. In any event, it behoves the engineer to look cautiously at published data, and to examine the fundamental physical property values from which other values may have been calculated.

One example of this point is the values for the heat capacity of liquid lithium. Fig. 1 shows the values obtained by six different sets of investigators in six different laboratories. The preferred values[6] give a heat capacity of approximately 1 cal/g over a fairly wide temperature range, but a casual dip into the literature for a single value could give a very different answer, as can be seen from Fig. 1.

Another example concerns published values for the heat of fusion of lithium—an important engineering property in designing a liquid-metal heat-transfer system, or even a proper melt pot for the addition of liquid lithium to a chemical process vessel. Thus, even as recently as 1952, when the second edition of the *Liquid Metals Handbook*[12] was published, a value of 158 cal/g was accepted. More recently, Kilner[11] and Douglas *et al.*[6] have arrived at a value of about 100 cal/g. There are values in the literature for this same property as low as 32 cal/g, as discussed by Miller.[12]

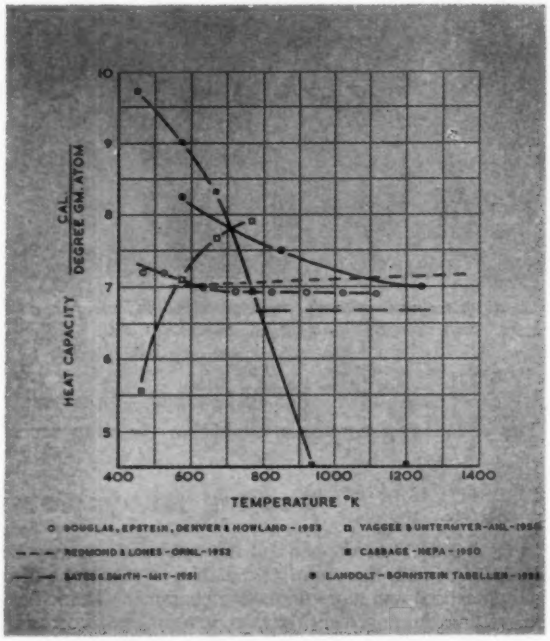

Fig. 1. Diagram showing the values obtained by six different sets of investigators in six different laboratories for the heat capacity of liquid lithium.

Lithium Alloys

The most important single point to emphasise about lithium in metallurgy is that it is *not* just a scavenger for oxygen, sulphur, etc., but that it *is* an alloy-former with considerable promise.

Although the Germans did some work on lithium alloys during World War I which resulted in the development of Bahnmetall as an ersatz railroad bearing metal, lithium-lead alloys have been largely neglected from that day to this. While Bahnmetall contained 0.04% lithium (0.58% sodium, 0.73% calcium and the balance lead), recent work at the Oak Ridge National Laboratory of the U.S. Atomic Energy Commission has shown that the eutectic (0.67 weight % Li) lithium-lead alloy has unusually high strength, even at elevated temperatures.

A second field of lithium alloy formation where early work was done in Germany during World War I involves light structural alloys. Here the Germans developed Schleron, having the following typical analysis:

	%
Aluminium	82.02
Zinc	13.20
Copper	3.14
Manganese	0.72
Iron	0.49
Silicon	0.35
Lithium	0.08

Mr. Sittig *is president and managing director of the American Lithium Institute, Inc., Princeton, New Jersey, U.S.A.*

TABLE 1.—Physical Properties of Lithium Metal

Property	Temperature °C	Temperature °F	Metric (scientific) units	British (engineering) units	Reference
Density	20	68	0.534 g/cc	33.7 lb./cu. ft	Been *et al.*[3]
	400	752	0.490 g/cc	30.6 lb./cu. ft.	
	800	1472	0.457 g/cc	28.6 lb./cu. ft	
Melting Point	179	354	—	—	Bohm and Klemm[4]
Boiling Point	1317	2403	—	—	Devaney[5]
Heat of Fusion	179	354	103.2 cal/g	186 Btu/lb.	Douglas *et al.*[6]
Heat of Vaporisation	1317	2403	4680 cal/g	8420 Btu/lb.	Miller[12]
Viscosity	200	392	5.62 millipoises	11.1 kin. units	Novikov *et al.*[13]
	400	752	4.02 millipoises	8.2 kin. units	
	600	1112	3.17 millipoises	6.7 kin. units	
Vapour Pressure	727		0.78 mm	0.015 psi	Douglas *et al.*[6]
	1077		91.0 mm	1.76 psi	
Thermal Conductivity	216	420	0.109 cal/sec. cm. °C	26.5 Btu/hr sq. ft °F	Webber *et al.*[15]
	539	1002	0.073 cal/sec. cm. °C	17.6 Btu/hr sq. ft °F	
Heat Capacity	100	212	0.90 cal/gm°C	0.90 Btu/lb.°F	Douglas *et al.*[6]
	300	572	1.02 cal/gm°C	1.02 Btu/lb.°F	
	800	1472	0.99 cal/gm°C	0.99 Btu/lb.°F	
Electric Conductivity	0	32	1.34 microhm-cm	—	Guntz *et al.*[10]
	100	212	12.7 microhm-cm	—	
Surface Tension	200-500	392-932	about 400 dynes/cm	—	Taylor[14]

While later German work by Assman[2] has shown that aluminium containing 1% lithium has a high tensile strength, most recent metallurgical research on lithium alloys has been concentrated on magnesium alloys. Work on this has been done by the Dow Chemical Co. at Midland, Michigan, and by the U.S. Bureau of Mines at Rolla, Missouri, as well as by other laboratories. This work has been concentrated on magnesium alloys containing an excess of 10% lithium, since it has been discovered that this percentage of lithium converts the hexagonal-close-packed crystal structure of magnesium to a cubic crystal structure in this alloy range. Such alloys offer the promise of the highest strength-to-weight ratio of any alloy known, and offer it in an alloy which is more workable than pure magnesium. Unfortunately, however, such alloys at present exhibit an ageing phenomenon which results in glass brittleness after service much above room temperature. Research is going on in an effort to solve this problem.

Zinc die-casting alloys containing 0.6% lithium have been found to exhibit decreased porosity and considerably increased tensile strength and beryllium alloys containing lithium show interesting promise in other ways. These alloys would be extremely light and might provide a form of beryllium which would be more easily worked than the virgin metal.

Knowledge of the alloying abilities of lithium, however,

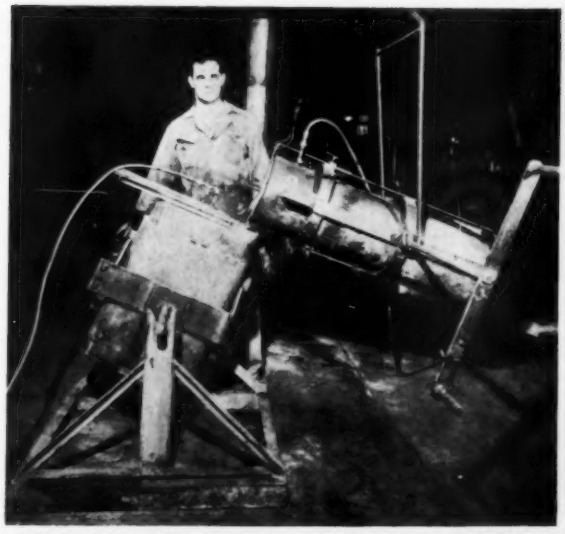

Fig. 2. Laboratory arrangement for pouring 100-lb. experimental ingots of magnesium-lithium alloys. A flow of argon is maintained in both crucible and mould. (Photo: Battelle Memorial Institute.)

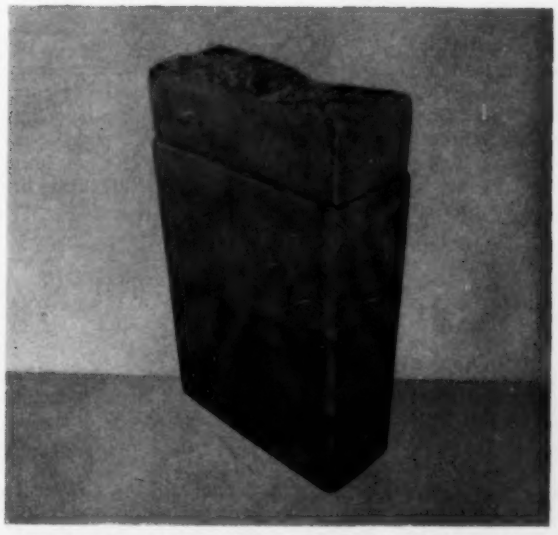

Fig. 3. Ingot of Mg alloy with 13% Li, 6% Al made with the equipment shown in Fig. 2. Ingot as shown weighs 95 lb. Its dimensions, exclusive of hot top, are 18 × 14 × 6 in. (Photo: Battelle Memorial Institute.)

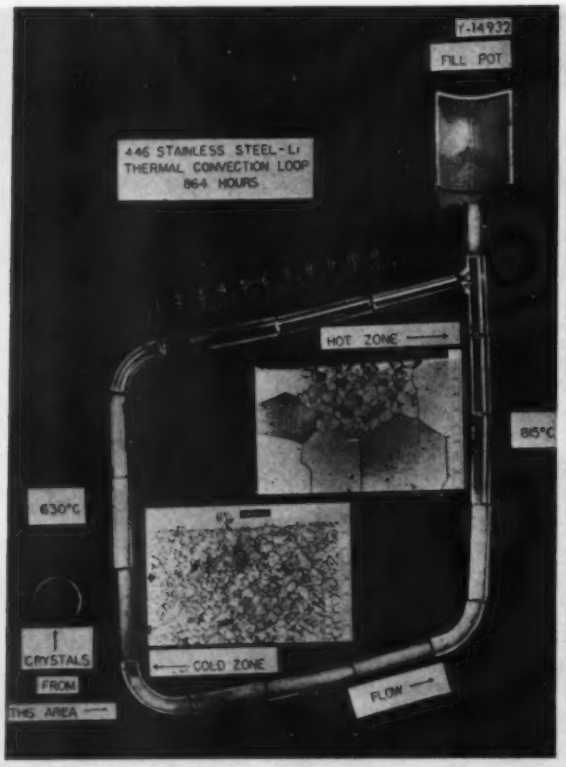

Fig. 4. Cross-section of thermal convection loop for the study of corrosion by molten lithium at high temperatures. The insets show enlargements of photomicrographs of specimens obtained after tests.

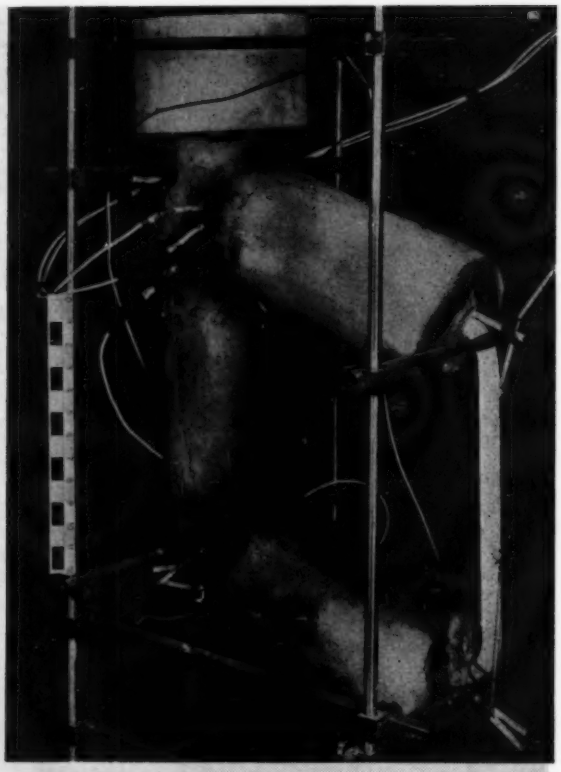

Fig. 5. Exterior view of terminal convection loop (same as that in Fig. 4) in operation. (Photos: Metallurgy Division, Oak Ridge National Laboratory.)

are rather limited, as is shown in Table 2. In view of the interesting results obtained by recent investigations of a few systems, as outlined above, the research potential here would seem to be quite large.

Liquid-metal Heat-transfer Systems

In addition to its use in alloys, lithium metal may have an interesting future in liquid-metal heat-transfer systems. As seen from Table 1, lithium has a very desirable combination of properties for heat-transfer applications such as high specific heat; large liquid range; high thermal conductivity; low viscosity; and low density. The last item, low density, makes lithium of particular interest for coolant systems in aircraft or missiles.

To counter-balance these advantages, there are two major problems which are as follows:

(1) Liquid lithium can be a corrosive material, particularly if not kept scrupulously free of oxygen and of nitrogen.

(2) For nuclear applications, the desirable coolant is not just lithium, but the isotope, lithium-7, which has a much lower thermal neutron absorption cross-section (1.0 barns) than does naturally-occurring lithium (70 barns) and especially the other isotope, lithium-6, which has a cross-section of 912 barns.

The first of these problems is the subject of intensive study by various contractors connected with the development of a nuclear-powered aircraft, because of the obvious attractiveness of lithium for such an application. Analytical techniques for minor impurities in lithium metal are being improved and mechanical techniques for blanketing and filtering the molten metal are undergoing intensive research.

The second problem will require more work in order to make it economically attractive. At the present time, quite pure lithium-6 is available from the U.S. Atomic Energy Commission at 2 to 3 cents/mg ($9000 to $13,000 a lb.) and relatively pure lithium-7 at 15 to 30 cents/mg ($70,000 to $130,000 a lb.). These prices are, of course, only for small experimental quantities, but give some idea of the challenge which is offered by large-scale production of the pure lithium-7 isotope.

Polymerisation Catalysis

While the alkali metals in general have long been known as polymerisation catalysts for dienes and other unsaturated hydrocarbons, lithium has received little attention for this use. This neglect has probably been due to the relative unavailability of lithium in the past, and to the fact that lithium-catalysed polymerisations seemed to be slower than those catalysed by sodium.

Increased knowledge of how to determine polymer structures, and of how to correlate these structures with performance characteristics, have combined with present-day availability of lithium, and improved knowledge of how to handle lithium to change this picture. The change began when researchers at the Firestone Tyre & Rubber Co. in Akron, Ohio, discovered that dispersions of lithium metal in hydrocarbons polymerised isoprene into a *cis*-polymer which is a truly synthetic natural rubber. The unique effect of lithium, as opposed to the other alkali metals, on polyisoprene polymer structure is shown in Table 3, which

TABLE 2.—State of Knowledge Concerning Lithium Alloy Systems

Phase Diagrams Established	Some Data on System	Probably Insoluble	No Data Available
Aluminium	Antimony	Chromium	Barium
Cadmium	Boron	Iridium	Columbium
Calcium	Beryllium	Iron	Germanium
Copper	Cæsium	Molybdenum	Hafnium
Indium	Gallium	Osmium	Manganese
Lead	Gold	Palladium	Strontium
Magnesium	Nickel	Platinum	Tantalum
Mercury	Rhenium	Rhodium	Thorium
Potassium	Rubidium	Ruthenium	Titanium
Silver	Selenium	Tungsten	Vanadium
Sodium	Silicon	Uranium	Zirconium
Thallium	Tellurium		
Tin			
Zinc			

TABLE 3.—Microstructure of Polyisoprenes made with Various Catalysts

Catalyst	% cis 1, 4-polymer	% trans 1, 4-polymer	% 3,4	% 1,2
Lithium	94	0	6	0
Sodium	0	43	51	6
Potassium	0	52	40	8
Rubidium	5	47	39	8
Cæsium	4	51	37	8
Alfin (sodium)	27	52	16	5
And for Comparison:				
Hevea rubber	97	0	3	0
Emulsion polymer ...	22	65	7	6

is taken from a paper by Foster and Binder.[9]

A series of patents is now being issued on this Firestone work, including two granted in Australia,[7, 8] and eight granted in Spain and in Italy with more than 70 additional applications pending in the United States and other countries. The Australian patents cover butadiene-styrene copolymers and isoprene-styrene copolymers, as well as isoprene-butadiene copolymers and polybutadiene. Work on diene polymerisation by lithium and lithium compounds is going on in many other laboratories, as would be expected in a competitive field such as the rubber industry. It is reasonable to expect that research will also be carried out on the polymerisation of other monomers by lithium, since lithium does seem to have a definite stereospecific action, and since such polymers are so much in demand.

A second major possibility for lithium in polymer catalysts is in modified Ziegler catalyst systems. Here, instead of using lithium or an organolithium compound alone, the interest is in substitution of an organolithium compound for the organoaluminum compound in a mixture with a titanium salt. The organolithium compounds are generally easier to prepare and easier to handle than are their organoaluminum counterparts.

High-energy Fuels

Here, unfortunately, is a field heavily veiled in military secrecy. When corners of the veil are occasionally lifted, tempting glimpses of interesting possibilities for lithium are seen. The term "high-energy fuels" as used today is usually applied to the boron hydrides, although the term is really much broader and includes any fuels whose Btu content is higher than that of conventional petroleum hydrocarbon fuels. Thus, slurries of metals in hydrocarbons, and other metalhydrides or metalorganics, all fall in the "high-energy fuel" category.

As far as the boron hydrides are concerned a conventional route to diborane is the reaction of lithium hydride with boron trifluoride etherate, as pointed out by Weilmunster.[16] Indications are, however, that lithium hydride in a slurry in some solvent such as ether is reacted with boron trichloride to produce diborane.[1] The diborane is then pyrolysed to pentaborane and decaborane. These materials may then be alkylated to give the final high-energy fuels.

There is, of course, an alternative route to the diborane, based on sodium borohydride as the raw material. Whereas the Olin-Mathieson Chemical Corp. has evinced much interest in the lithium-based route, the Callery Chemical Co., the other major HEF producer at the moment, seems to have cast its lot with a sodium-based process. Only time will tell which route to which high-energy fuel composition proves superior. Then the magnitude of the market will be determined by the military competition between ballistic missiles, chemically-fuelled aircraft, and nuclear-powered aircraft, all within the framework of an ever-changing overall military budget. It is probably safe to say that, in high-energy fuels (and in the other applications of lithium metal as well), the sky is the limit!

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Fig. 6. Illustration of commercial facilities for the production of lithium hydride from lithium metal. (Photo: Lithium Corporation of America Inc.)

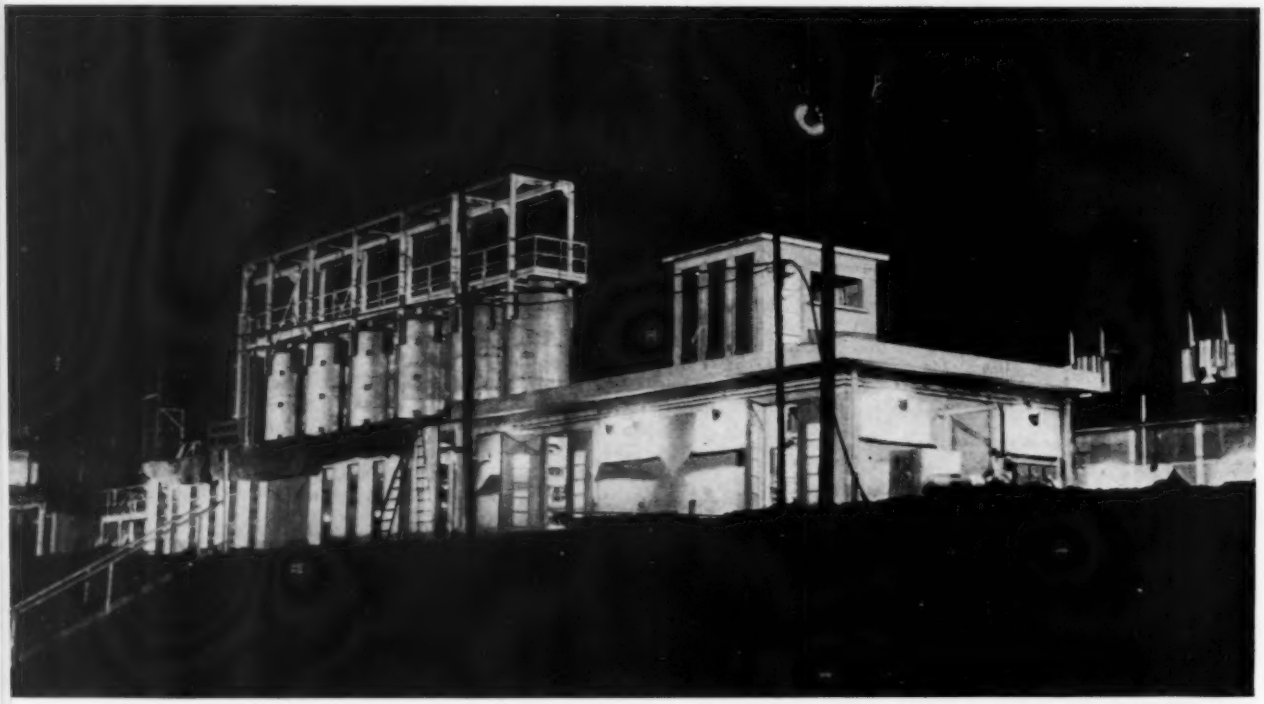

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Fig. 1. Night view of the plant connected with the Beynes underground gas-holder.

UNDERGROUND STORAGE OF GAS AT BEYNES (SEINE ET OISE)

A unique method of solving the town gas storage problem—imitating Nature's own way of retaining natural gas—has been adopted by Gaz de France. An underground natural dome structure of porous sand capped by impermeable clay forms the store

CONSUMPTION of gas has continually increased since the war throughout the whole of France (3 milliards 430 million cu. m in 1956 against 2 milliards 343 million in 1947) and notably in the Paris region, which itself absorbs roughly one-half of the gas consumed in France. On the other hand, experience has shown that the daily demand for gas is more and more related to the ambient temperature because of the development of gas heating in dwelling houses. In Paris in the month of January three or four times more gas is consumed than in the month of August. It is estimated that in 1961 and 1962 the daily consumption of the Paris region for a temperature of −10°C at le Châtelet will be approximately 10 million cu. m, although the current means of production only assure 7 million cu. m a day. To this must be added a supplement of 1 million cu. m a day supplied from the eastern artery, from the coking plants at pits and ironworks in Lorraine.

To meet the needs of this consumption, it would be necessary to have available gas-holders containing not just some hundreds of thousands of cu. m but some tens of millions. This would mean a 200-fold increase of gas-holder capacity—a quite uneconomic proposition.

Gaz de France therefore turned towards underground storage of gas to solve the problem, thereby avoiding the construction of new plant and at the same time making the most economic use of existing installations throughout the year. The reservoir absorbs the excess gas during the summer and provides the necessary supplement of gas during the winter. Underground storage also allows the supplies from the eastern artery to be accepted on a regular basis, ensuring a high coefficient of utilisation. The advantages of

Fig. 2. Arrival of gas at the Beynes installation, where it will be purified and compressed before storage.

Fig. 3. Pipe network serving the plant connected with the Beynes underground gas-holder.

this bold technique are not only economic. Underground storage of gas at Beynes gives a considerable improvement in the regularity and the quality of gas distribution in the Paris region.

These considerations induced Gaz de France at the end of 1954 to undertake research on a convenient geological structure situated close to Paris, in collaboration with specialists of l'Institut Français du Pétrole and of la Société Nationale des Pétroles du Languedoc Méditerranéen. It was not a question of discovering a cavern, but a zone of porous and permeable terrain covered by an impermeable bed of such a form that the gas introduced underneath this "cover" could not escape. These conditions were met not far from Versailles under the forest of Beynes where a dome structure was located as a result of numerous drillings. This is a water-bearing *nappe* formed by a particularly porous and permeable sand covered by a bed of impermeable clay. This *nappe* is situated at a depth extending between 307 and 325 m and has the following dimensions: thickness between 7 and 12 m; length about 5 kilometres; and breadth 2 kilometres. The water pressure is about 39 kilograms per sq. cm.

This formation will hold 320-340 million cu. m of gas but not all of this can be used, since some gas must be retained to prevent water from sealing the shafts. The volume of gas annually disposable will be of the order of 150 million cu. m, which is likely to be sufficient to cover the needs of the Paris region in the course of the next year.

To obtain the same capacity of gas storage it would be necessary to construct 700 giant gas-holders of 225,000 cu. m capacity, which would be very expensive. It is calculated, in fact, that the equipment of an underground reservoir is some 200 times cheaper than the metallic gas-holder for every cu. m stored.

The underground reservoir is connected to the regional network of gas distribution by a conduit of 400 mm diameter, 28 km. long. This feeds the "belt" which goes all round Paris, supplying the suburbs at high pressure and also the neighbouring regions from Fontainebleau to Mantes and Creil. The project has required, in addition to the drilling of some dozen shafts and their collecting network, the following constructional work.

A 28-km conduit to connect the network (at Viroflay) with the high-pressure belt, which in turn is connected to the eastern artery via the main station at Alfortville; a station at Viroflay for regulating and conditioning the gas injected or withdrawn; and a compressor house for pumping gas to the shafts. A plant for drying the gas withdrawn from storage has also been provided.

During October, 1957, gas was pumped to the reservoir at a rate of 400,000 cu. m a day which was sufficient to build up a stock of almost 50 million cu. m. These stocks allow for withdrawals at the rate of 300,000 to 400,000 cu. m a day during the winter of 1957/58, and at 1 to 1.2 million cu. m a day during the following year.

Having completed this vast experiment, the fillings should be completed in the normal course of events in the course of the year 1959, and the reservoir will then supply a daily volume of the order of 2.5 million cu. m.

The researches of Gaz de France on underground storage are not limited to the single structure of Beynes. The rational exploitation of the future network of gas transmission (natural gas, coke-oven gas, refinery gas) and the increasingly seasonal character of consumption necessitates the provision of new underground reservoirs. That is why methodical reconnaissance of the structure of Vernon (Eure) is being actively pursued and other formations have already been identified, in particular in the Centre-Est, in Limagne and in the region of Chalôn-sur-Saône.

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FIRE DANGER FROM STATIC ELECTRICITY

This article describes the generation of static electricity, the nature of the fire hazard it creates and the methods by which charges may be safely dissipated

by J. H. McGUIRE, B.Sc., A.M.I.E.E., A.Inst.P.

THE importance to industry of the fire hazard from static electricity is greater than might appear from the small number of fires originating from this cause which are reported to fire brigades in the United Kingdom.* The reasons for this danger being more real than is indicated by these figures are as follows:

(1) In many industrial processes, involving flammable vapours, fires due to static frequently occur and are dealt with without the fire brigade being notified.

(2) Stringent precautions are already adopted to eliminate static electricity because of its known fire hazard and of the nuisance it creates otherwise.

(3) A discharge of static, when it does occur, often results in an explosion with the attendant risk of casualties.

Generation of Static Electricity

The generation of static charge is essentially a surface phenomenon associated with the separation of two surfaces. It may be interpreted as a contact potential effect resulting from the transfer of electrons or even ions[1] from one surface to another in contact with it. The order and sign of the charge generated is dependent on the following factors:

(1) *Area of Surface Intimately in Contact.* This affects the magnitude, not the sign of the charge generated. It is of great importance, however, since, as stated, static charge is a surface phenomenon, and the areas coming into intimate contact in practice are dependent on the nature of the surfaces and the pressure between them.[2]

(2) *Combination of Materials Involved.* Attempts have been made to list materials in a sequence so that, for any combination, the one appearing earlier in the list will always be charged positively. Different workers have produced contradictory lists and this has raised the question of whether such a sequence exists. Shaw and Jex[3] claim, for example, that it is impossible to derive one simple sequence covering all materials, but that, within any one class of materials, e.g., glasses, metals or textiles, such a sequence might be a reality. It is possible that the correct series has not been produced yet, because other factors, such as friction and surface impurities, have influenced measurements. As recently as 1954 Trinchieri[4] put forward an electrostatic series.

(3) *Temperature Differences Between Surfaces.* It has been demonstrated that static charges can be produced when two samples of the same material are rubbed together so that different areas of the two surfaces are involved. Henry[5] reached the conclusion that the charge separation is a kinetic effect analogous to the thermal diffusion of gas molecules through a porous plug from the hot to the cold side of a container. He attributes the charge separation to the thermal gradient across the interface. I see no reason, however, why this effect and the effect of using different materials should not be grouped together. Charged particles, either electrons or ions, will pass between one surface and the other and the net transfer will be dependent on the relative densities of charged particles on the two surfaces and on the energy potentials of the particles. The special effects of temperature gradients then stand in relation to the rest of static phenomena, as do thermo-electric effects to contact potential. Henry has recently developed a theory along these lines.[6]

(4) *The State of Strain of the Two Surfaces.* The theory that the state of strain of the surfaces influences the generation of static electricity has been put forward by Shaw.[7] Henry,[5] however, suggested that the effects attributed to strain might have been due to extraneous temperature gradients. It would be interesting to compare the effects of strain claimed by Shaw with those on the contact potentials of metals.

The part played by friction, which influences the generation of charge to a greater extent, is best interpreted in terms of its two secondary effects. It substantially increases the areas of surface coming into intimate contact and it creates temperature differences between elements of the contacting surfaces. These factors also govern the generation of charge at fluid-solid or fluid-fluid interfaces except that, where electrolytes are involved, the principal effect occurs within the fluid on the separation of the flowing liquid and the fixed laminar layer. Work on the electrification of fluids has been surveyed by Moore and Proudfoot.[8]

Several theories have been put forward to explain the mechanism by which static charge is generated and these have recently been reviewed by F. A. Vick,[9] P. S. H. Henry[6, 10, 11] and V. E. Gonsalves,[12] who, between them, give a total of some seventy references.

Mr. McGuire *has been engaged with the work of the D.S.I.R. and Fire Offices Committee Joint Fire Research Organisation since* 1949.

* For the years 1949 to 1953 the total number of fires, in which static electricity was the supposed cause, was: in buildings, 121, elsewhere, 6.

Fig. 1. Charging hose for feeding a horizontal kiln at the Barry works of Midland Silicones Ltd., showing electrical bonding installed to obviate electrostatic hazards.

Discharge of Static Electricity

When the potential at the surface of a body reaches a value so that the dielectric field strength of the surrounding medium is attained then a discharge occurs. Usually the surrounding medium is air and the limiting value of the electric field strength which can be attained is of the order of 30,000 volts a cm.[13] The most obvious circumstances in which a substantial discharge will occur is when the body acquiring charge is an insulated conductor. The conductor almost completely discharges and the energy of the discharge is, neglecting any small residual charge, $\frac{1}{2} CV^2$, where C is the capacity of the conductor. A body can usually be considered to be a conductor of static electricity when its relaxation-time constant is sufficiently short for substantially all its electrical energy to be dissipated in a spark discharge. Resistivities of less than 10^5 ohm/cm. will give relaxation times of less than a microsecond, so that many materials (including liquids), conventionally described as non-conducting or even insulating, may be classified as conductors from this point of view.

Where both materials are insulators, dangerous discharges can still occur, although the most hazardous are generally those in which the discharge takes place between two associated conductors and does not directly involve the materials generating the static. Firstly, a conductor can be charged by induction, that is, it can assume a potential as a result of the proximity of the charged material. This effect is most marked where the conductor entirely surrounds the charged material and thereby behaves as if it had acquired the same charge as the material. Secondly, the high electric field strengths produced around sharp points by relatively low potentials are able to impart sufficient energy to charged particles to allow them to overcome surface attractions and escape. Thus if an insulating belt is being continuously charged by contact with a roller it can pass its charge to a pointed or sharply rounded conductor nearby. This process can continue until the conductor tends to the potential of the belt.

Discharges may occur directly between elements of an insulating material and an earthed conductor and it is possible that the energies involved may be sufficiently large to ignite flammable mixtures. Where gases, dust dispersions and fluids of high resistivity (e.g., greater than 10^{12} ohm/cm.) are involved, hazardous discharges are almost invariably associated with an insulated conductor from which the charge has been removed (e.g., the pipe through which the fluid was flowing), with an insulated conductor to which the fluid has passed charge or with an insulated conductor which has become charged by induction. The possibility of a diffuse discharge occurring between an earthed conductor and a mass of high-resistivity fluid cannot, however, be ruled out.[14]

Examples of the Fire Hazard

The following are examples of how fires or explosions can be initiated by the generation and subsequent discharge of static electricity.

In hospital suites there may be present mixtures of flammable vapour with air or oxygen present which can be ignited by spark energies as small as 200 or 1 μJ[15] respectively. Thus the withdrawal of a blanket from a non-conducting rubber-covered mattress presents a hazard,[16] for the resultant charge on the rubber can induce a considerable charge on an insulated bed or operating table. If the latter is of metal it can contribute all its electrostatic energy to a single spark discharge. Persons walking about in insulating shoes have been found to acquire hazardous charges.[17, 18]

Systems in which a material passes over a roller, at least one of the two being an insulator, are a common hazard in industry. Hazardous discharges generally occur between conductors either directly or indirectly associated with the sources of the charge, but I have visited the scene of one fire in which it appeared that the discharge from an insulator to an earthed conductor was the only possible cause. The process involved the spreading of a solution of

paraffin wax in petrol on to linoleum passing between two earthed steel rollers. A further example of such a fire was in an adhesive tapes factory where fires occurred around a similar type of machine in which all metal parts were earthed. Belt drives are a particular example of such systems in which conditions are most favourable for the generation of very high potentials, possibly of up to a million volts.[19] Speeds are often high and if leakage resistance is low the repetitive nature of the operation allows a progressive build-up of charge. Given a suitably disposed nearby conductor, a belt drive behaves as a Van de Graaf generator. Hence, despite the fact that the spark-iginition energies of most of the chemically stable, but ignitable dust clouds found in industry lie in the range 0.01 to 2.5J,[20, 21, 22, 23] compared with a range of the order of 0.0002 to 0.01J for most gases and vapours,[20, 24] spark energies which will initiate explosions of these dusts can be derived from a belt drive.

The electrostatic hazard associated with the flow of liquids is well known. The Avonmouth explosion and fire[25] is an example of an incident which occurred despite the exercise of considerable care. Fuel was being pumped into an earthed tank through an earthed feed pipe and it is believed that charge from the liquid accumulated on a conducting dipping rod. When a sufficient potential had built up, it discharged to the tank. In the United States, where atmospheric conditions are often more suitable for the build-up of static electricity, it has been reported[26] that a fire due to static electricity occurred when a chauffeur poured petrol from a five-gallon drum through a chamois leather stretched over a funnel and hence into the tank of a motor car.

Dale[19] refers to several accidents in coal mines in which the use of dust-laden compressed-air lines ignited fire damp. In each case, however, the discharge took place between an insulated section of the supply line and earth, and earthing of the line would have prevented the accidents. Transfer of the charge in a gas, or on particles suspended within it, to an insulated conductor or to an insulator which then charges a conductor can, however, produce dangerous conditions. Dale[19] described French and Belgian laboratory experiments which illustrate this. Sparks 13 mm. long have been drawn from a 2-mm. diameter galvanised-iron wire held in front of the orifice of a compressed-air line. In other experiments, blocks of coal, limestone and carbon were placed on an insulated sheet of galvanised iron and subjected to a blast of air and sand and metal filings from a compressed-air line. Sparks capable of igniting fire damp were obtained from the galvanised-iron sheet. The generation of static by wet steam jets was recorded as long ago as 1840 by Lord Armstrong[27, 28] and the effects to be expected when steam leaves a pipe-line or impinges on a surface are similar to those described above.

Preventive Measures

Modern knowledge on methods of reducing or eliminating the fire risk created by static charge has been summarised by the National Fire Protection Association[29] and by Bulgin[30] and will only be dealt with briefly here. It is customary to aim at dissipating charges at such a rate that hazardous levels are never built up. With this end in view, all metal parts, in regions where static electricity is generated, are earthed. Although it is difficult to generalise, rates of generation of static are usually much less than a micro-amp (e.g., Fordham Cooper[31] considers 10^{-8} amp a high value) and voltages in excess of 300 (and usually of the order 5-50 kV dependent on the capacity involved) are necessary before hazardous discharges can occur. To eliminate the fire hazard created by static, metal parts or other conductors (see p. 137) can therefore be considered earthed even if the earth resistance is as high as 10^8 ohms. Estimations ranging from 10^7 to 10^{11} ohms are given by other workers[31, 32, 33] for the value of the safe maximum earthing resistance under various circumstances.

It has been found practical in hospital operating suites[34, 35] and in industry to earth mobile metal equipments with conductive (or anti-static) tyres and conductive floors. The resistivities of this protective equipment are generally high enough to guard against the danger of shock or ignition due to leakage of excessive currents from 250-V. electricity supply mains. Where finished products are being considered, a lower limiting resistance value of 100 K Ω[36] between the main body of the product and earth is generally regarded as meeting this requirement. British Standard 2050: 1953[36] prescribes maximum values of resistance ranging between 10^6 and 10^7 ohms for various finished products made of rubber, but these values are intended to cater for an increase in resistance with age. In the foreword to the British Standard there is stated: "Experience has shown that, for anti-static purposes, the limits of electrical resistance of a product at any time in its life should lie between 10^5 and 10^{10} ohms, and preferably between 10^5 and 10^8 ohms." It is recommended that products with resistance values within the prescribed limits be described as "anti-static", and those with lower values as "conductive".

The use of trailing metal chains as a means of earthing mobile apparatus, vehicles, etc.,[37] often serves little purpose in reducing static owing to the remarkably high resistance which can result from dirt or corrosion between links or between a link and the floor. Johnson[38] cites cases where several thousand volts were required to break down the insulation resistance. Generation of static on persons walking about can be eliminated by the combined use of conductive or anti-static flooring and footwear.

The most desirable method of dissipating static is to make the generating surfaces themselves conductive. As two elemental surfaces are separated and a potential difference appears between them, a current flows along the surfaces to points at which they are still in contact. Conductive or anti-static rubber is an example of a material which has been rendered conductive and work is progressing on methods of manufacturing conductive plastics.[39]

Where the materials generating static are essentially insulating, static hazard and nuisance are often eliminated by surface treatments, e.g., by coating the surfaces with conducting liquids. Examples of this are to be found in the textile industry[40, 41] and in many locations where static from belt drives[42, 43, 44] must be reduced

Where it is not possible to render a material or its surface conducting, the charge on a surface can be dissipated by ionising the surrounding air by an external agency such as a high-voltage (but low-energy) discharge or a radioactive source. The electric static eliminator is sometimes held to be itself a source of hazard, either because faulty insulation or design might give rise to an unwanted dangerous discharge, or because of the proximity of particularly dangerous gas mixtures which might be ignited even under normal operating conditions. Radioactive static eliminators will, of course, present a health hazard if operatives enter the region which is being irradiated. Both alpha and beta sources are used in British eliminators and the effective ranges in the regions exposed to radiation are of the order of, respectively, $\frac{1}{2}$ in. and 12 in. To increase the effective range, one manufacturer has incorporated an alpha source in an air blower. In designing a radioactive static eliminator, care must be taken to ensure that the radioactive material will not be dispersed in the event of a fire. Where the levels of static are such that only an accumulation of charge over a period of, say, several

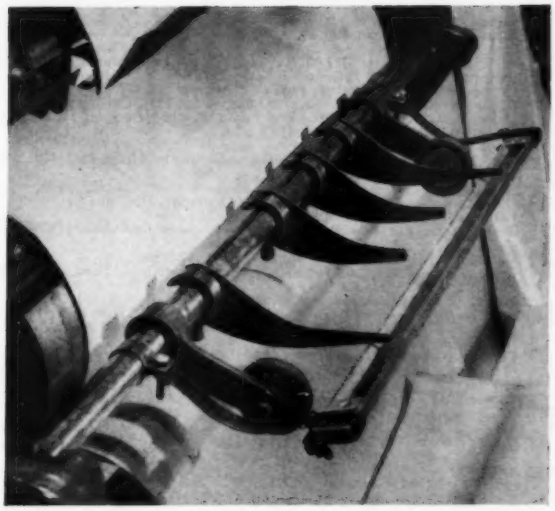

Fig. 2. A radioactive static-electricity eliminator at the paper works of John Dickinson & Co. Ltd., Hemel Hempstead, Herts.

seconds would be hazardous, the charge itself may be used to ionise the surrounding air. This may be achieved by locating sharp-pointed earthed conductors near the generating surfaces. The high field strength near the sharp points will then result in a continuous discharge (corona effects). A fine wire stretched near the generating surface and earthed is sometimes adequate. Although a high atmospheric humidity will often eliminate static electricity[45, 46] high levels of static may be generated on hydrophobic materials such as polythene, even in atmospheres with a high relative humidity.[47]

Where rapid flows of gases and dust dispersions are generating static the density of charge on the gas or dispersed dust does not, of itself, constitute a hazard.[48] Risk of spark discharge is more frequently associated with metal parts and is usually eliminated by using earthed conductive pipe-lines and by ensuring that high-pressure jets do not play on an insulated conductor or on an insulator which can charge an insulated conductor by induction. If flexible pipe-lines are made from an insulating material and an earthed wire is incorporated in each length of pipe-line, it must be ensured that the wire will never fracture during the life of the pipe-line. Should this occur, conditions could be very dangerous, since a section of the pipe might constitute an insulated conductor since the break in the wire would, if not embedded in the pipe material, provide a spark gap.

Where powders or dusts are flowing in bulk, for example from a chute into a container, then even if the latter is earthed the charge retained by the bulk of dust or powder may be substantial and a discharge might occur between the surface of the powder and an earthed point.[48] The rate of flow and the size of the container might be reduced or, possibly, the air immediately above the surface of the powder ionised to avoid the danger. Liquids often give rise to the same risks as gases and dusts and the same precautions must be taken. The hazard regarding bulk transfer is particularly important, since it arises much more frequently and to a greater degree than with dusts and powders. The most desirable way of reducing this hazard would be to render offending liquids conducting so that their bulk charge relaxation time constant $K\rho/4\pi$ (where K = specific inductive capacity and ρ = resistivity in e.s.u.) is small.

Fordham Cooper[49] suggests that bulk resistivities of 10^{11} ohm/cm. or less will relax charges sufficiently rapidly to make them substantially undetectable. A resistivity of 10^{11} ohm/cm. will generally give a relaxation time constant of the order of $\frac{1}{100}$ second or possibly up to 1 second for materials with a high value of specific inductive capacity (K).

Additives, mainly oleates, have been found[50] which will render trichlorethylene and white spirit sufficiently conducting to eliminate static nuisance in the dry-cleaning industry. The additives were developed with a view to increasing conductivities of the duration of specific processes and no information is available as to whether the high conductivity is maintained under storage conditions. It would be very desirable if an additive could be found to make petrol sufficiently conducting. Triethanolamine oleate in a proportion of 0.2% has been found adequate, but it appears to be in suspension and it precipitates within some 30 minutes unless the petrol is agitated. Methyl alcohol reduces the resistivity but must be used in considerable concentration. No satisfactory method of eliminating the static hazard involved in pumping petrol has yet been devised and rates of flow are sometimes restricted when conditions are particularly dangerous.

Different combinations of materials produce different quantities of charge on being separated and it is sometimes feasible to choose a combination which will not produce a hazardous charge. Such an approach is unusual, however, since surface impurities and variations in the temperature difference between the two materials involved can completely alter conditions.

Information regarding the hazard created by static electricity and the available methods of dissipating it has been summarised by various authorities.[29, 30, 51]

Further Work

Further work is required on the following four aspects of the hazard created by static.

(a) Where the flow of a non-conducting liquid generates a considerable charge, which may be particularly dangerous if the liquid is flammable, some satisfactory method of reducing the hazard is required. The most practical approach appears to be a search for additives which form stable emulsions and which would reduce resistivities to levels of the order 10^{11} ohm/cm. or less so that charges would be dissipated in a fraction of a second and would not build up. With the possible exception of the substances referred to by Wagg[50] developed for use with trichlorethylene and white spirit, no such additives are known. A programme of work might profitably include an investigation into the mechanism by which additives render non-polar liquids conducting.

(b) More information, qualitative and quantitative, is required regarding the generation of static in practice with particular reference to the synthetic high polymers now in general use. The most rewarding approach to this problem, from the long-term point of view, would probably be to measure the charges generated under carefully controlled conditions in which, in the first instance, such factors as temperature difference and strain were eliminated. This would probably produce an electrostatic series. If the effect of such factors as temperature, temperature difference and strain were then determined, their effect on the sequence of an electrostatic series would become apparent and the sum total of the results would give quantitative information on the levels of charge to be expected. By determining, separately, the areas of surface coming into intimate contact and the dissipation of the charge as it is generated, the quantitative information might be given a more fundamental significance. The above information in conjunction

with the information already available on the minimum spark energies required to ignite dusts,[21, 22, 23, 52] vapour-air[21, 24, 25] and vapour-oxygen mixtures[15, 25] could be used to assess the hazard associated with discharges from conductors.

(c) Information is needed on the nature of a diffuse discharge from an area of an insulating surface. An investigation is required into the conditions governing the magnitude of the area involved. With such diffuse discharges the minimum ignition energies referred to earlier might be higher, and if it were desired not to give exaggerated predictions of static hazard a determination of minimum ignition energies under diffuse discharge conditions might be called for.

(d) The use of corona discharges as a means of dissipating static either directly or by generating ions in the atmosphere, which subsequently migrate to the charged surface and neutralise the charge, may give rise to a fire hazard. Where the discharge is operated from a high-voltage power supply, the whole constituting an ion generator, the risk is at present considered to be important and the use of this form of static eliminator is restricted to applications in which no fire risk exists.

ACKNOWLEDGEMENT

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Gas Reforming Plant at Romford Nears Completion

MEMBERS of the Technical Press were recently shown round the Romford works of the North Thames Gas Board where the gas reforming plant for converting refinery gas to a composition close to that of towns gas is nearing completion. The North Thames Gas Board have agreed to take a supply of 25,000,000 therms a year (about 14 million cu. ft of gas a day) of refinery tail gases from the Shell Refining Co. for a period of ten years beginning in the middle of 1958. This is equivalent to the gas produced from 250,000 tons of carbonisation coals a year, and approximately 6% of the Board's total production.

The calorific value of the gases will range between 1000 and 2000 Btu, depending on the processes being worked at the refinery, but are generally about 1500 Btu. The principal constituents are hydrogen, ethane, propane, butane, ethylene and propylene. To economise in distribution costs, the high calorific-value gases are being pumped before reforming to a nodal point on the Board's existing distribution system at Romford. At the refinery they pass through the Girbitol process, where most of the hydrogen sulphide and some organic sulphur is removed by washing in an organic solvent. In a second stage, alkalis are used to remove some more of the hydrogen sulphide and some organic compounds. Finally, in a third stage, the gases are dried by passing through vessels containing alumina which absorbs the water. They pass through the metering and quality controls and leave the outlet at a pressure of 120 lb. per sq. in. The gases are then pumped through a steel main. The designed maximum working pressure in the pipes is 275 lb. per sq in., but the hydraulic test pressure is 400 lb. per sq in. At 275 lb. pressure the pipe itself will hold 5,000,000 cu. ft of gas, the equivalent of a storage holder costing £500,000.

The Romford plant will be operated on the Onia-Gegi principle. A portion of the gas is passed over a nickel catalyst with steam to convert the high hydrocarbons into a mixture mainly of hydrogen, carbon monoxide and carbon dioxide producing a gas with a calorific value somewhere in the region of 320 Btu per cu. ft. This gas is admixed in the cold with the remainder of the gas coming up the pipeline to give a material of 500 Btu with the same combustion characteristics as towns gas. The plant at Romford consists of four catalyst vessels, which will be capable finally of producing 36,000,000 cu. ft per day of 500-Btu gas. Part of the plant at Romford is also suited for using primary flash distillate or light spirit as a raw material and this could be used in the event of any failure in the supply of refinery gas.

Total cost is £1,789,000. The plant will produce as much gas as a conventional coal carbonising unit costing £4,380,000. The capital cost will be 1d. per therm as against 2.9d. per therm by traditional plant. It will be equivalent to building a new works sufficient to supply a town of 500,000 inhabitants. Later it is expected that tail gases from Coryton and methane from Canvey will add to the supplies.

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FOULING IN HEAT EXCHANGERS

Some comments on the usefulness of a recent article* on this topic are given below

by D. T. SHORE, M.Sc. (Eng.), A.C.G.I., A.M.I.Mech.E.

THE article "Does Fouling of Heat-exchanger Surfaces Always Mean Poorer Performance?" presents a picture of the effect of fouling deposits within the tubes of tubular heat exchangers and on one side of plate heat exchangers. What is of interest is the application of the data presented to the practical problems encountered by the designer of equipment.

Using the subscript $_c$ to denote clean conditions and the subscript $_d$ for fouling conditions and following the symbols used in the text, the authors derived formulæ

$$Q_d < Q_c \text{ when } Nu_d > 2m \quad \ldots . (1)$$

$$Q_d > Q_c \text{ when } Nu_d < 2m \quad \ldots . (2)$$

may be accepted. Nu_d is a rather confusing symbol, since it is not a true Nusselt number and cannot be compared with

$$Nu_c = aRe^m\ Pr^n \quad \ldots . (3)$$

where Nu_c is the Nusselt number for clean tube conditions. Nu_d is a quasi-Nusselt number given by

$$Nu_d = \frac{h_c D}{k_d}$$

where h_c is the clean tube film coefficient and k_d is the thermal conductivity of the dirt layer. A similar analysis for the plate-type heat exchanger yields

$$Q_d < Q_c \text{ when } Nu_d \geqslant 2 \text{ where } Nu_d = \frac{h_c b}{k_d}$$

Since the formulæ are only approximate solutions, we may conveniently use the expression $Q_d < Q_c$ when $Nu_d \geqslant 2$ for both tubular and plate heat exchangers and examine the properties and dimensions to give a particular solution.

The solution of interest is that giving the limiting value of the film coefficient h_c, say h'_c, above which fouling will give a reduction in the heat transfer.

Considering the fouling layer, e.g., carbonate scales, inorganic and organic milk scale and fouling from brine or sulphited liquors, etc., the thermal conductivity k_d will be less than 2 Btu/hr sq. ft °F ft, an din most cases less than 0.5. For a tubular heat exchanger with 1-in. bore tubes or a plate-type heat exchanger with a mean plate gap of 1/10 in. we may readily determine the critical clean film coefficient h'_c corresponding to $Nu_d = 2$.

Using the highest conductivity figure for the fouling layer, namely 2, then in the tubular machine the film coefficient h'_c for $Nu_d = 2$ is given by

$$h'_c = 24 \times k_d = 48 \text{ Btu/hr sq. ft °F}$$

Symbols

- a = a constant;
- b = width of slot or clearance between adjacent plates;
- c = specific heat of fluid or subscript denoting clean conditions;
- D = internal diameter of tube;
- h = film coefficient of heat transfer;
- h_c = film coefficient for clean tube;
- h'_c = limiting coefficient above which fouling will give a reduction in heat transfer;
- h_d = film coefficient when tubes are fouled;
- k_d = thermal conductivity of the fouling deposit;
- m = exponent of the Reynolds number;
- n = exponent of the Prandtl number;
- Nu = Nusselt number = $\frac{hD}{k}$;
- Pr = Prandtl number $\frac{c\mu}{k}$;
- Q_c = amount of heat transferred under clean wall conditions;
- Q_d = amount of heat transferred under fouled wall conditions;
- Re = Reynolds number $\frac{\rho DV}{\mu}$;
- ρ = density of the fluid; and
- μ = viscosity of the fluid.

while in the plate machine

$$h'_c = 240 \times k_d = 480$$

In the tubular exchanger we see that the limiting coefficient above which fouling will give a reduction in heat transfer is below the turbulent flow range, i.e., the argument does not apply. In the case of the plate-type exchanger, practical designs using a plate gap as low as 1/10 in. will give film coefficients greatly in excess of 480. Examination of the curves in Fig. 1 will show the film coefficients for both 1-in. tubes and a standard plate section plotted against the liquid velocity.

Apart from the theoretical consideration outlined above, considerable practical experience with plate-type heat exchangers, while sometimes showing less reduction in performance than might be expected, has never shown an improvement in heat transfer when fouling conditions occur.

Pressure loss in plate heat exchangers, while less than a tubular machine, with an equal surface area if performing the same duty, must be limited by mechanical design considerations. Thus performance cannot be judged on heat transfer alone. One of the general assumptions in the theoretical solution presented is a constant mass flow rate.

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* *British Chemical Engineering*, 1957, **2**, 674.

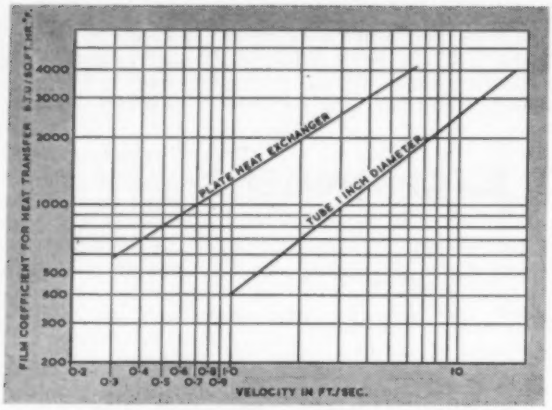

Fig. 1. Film co-efficients for water at 160°F.

The pressure rise, under fouling conditions, to maintain this flow rate may exceed the design pressure of the pumps or the heat exchanger. It may therefore be prudent to allow surface area in excess of the design load merely to limit pressure rise during operation under gradually fouling conditions.

Turning now to liquid to gas heat exchangers, since the above derivation is independent of the heat flux employed in the heat exchanger, the remarks will still apply to fouling on the liquid side. However, on the gas side, due to the low conductivity of gases, the ratio of the clean film coefficient to the conductivity of the dirt film is smaller, and hence one might consider the theoretical coefficient as improving due to the dirt film. We must now, however, consider the more practical aspect. In the case of air preheaters for furnaces, boilers, driers, reactors, etc., flow rate cannot be maintained under the fouling conditions due to either the fan or the process requirements, unless special provision has been made in the blowing system. The transport of gas by positive displacement is rare. In normal centrifugal fan design the discharge is related to the pressure. In furnaces and reactors where pressure control is important to the process, it would be impractical to raise the pressure continuously over the fouling period by an amount sufficient to maintain the flow rate.

It is suggested in the text that allowance might be made for fouling in a heat exchanger design by using the reduced cross-sectional area and hence a higher velocity. It is then pointed out that the performance will be low under clean conditions, i.e., before the fouling has occurred.

The designer would not do this, although he might calculate the velocity increase when determining his pressure loss. From this point of view, the value of the article has been reduced by the needless desire to show a theoretical improvement under fouling conditions. Its value lies in the rapid assessment of the minimum reduction in heat transfer that can occur.

Allowance for fouling in a heat exchanger design is a difficult matter. In some cases the fouling is temperature dependent, so that certain parts of the heat exchanger are more prone to deposits. In many cases there is an added surface roughness due to irregularities in the deposition, and this, in plate-type air preheaters, can give rise to high pressure losses, and, in the worst cases, maldistribution of the air throughout the heat exchanger pack, which again would give rise to a reduction in performance. It is therefore suggested that, in all practical heat exchangers, fouling will reduce the heat exchanger performance.

Recent O.E.E.C. Publications

Air and Water Pollution
1957, 218 pp., 18s.

THIS IS THE combined report of two missions which investigated air and water pollution in West Europe and in the U.S.A. They concluded that processes for treating town sewage had reached a satisfactory stage of development, but the same could not always be said for industrial effluents. Conditions are very serious in certain areas of the United Kingdom and Western Germany and, in general, Europe is less advanced than the U.S.A. in matters concerning air pollution. The extensive and detailed report includes a set of recommendations on technical and economic aspects, on the location of industries, legislation, research and European co-operation.

Production, Transmission and Distribution of Electricity in Europe
1957, 96 pp., 9s.

IN APRIL 1949, a Technical Assistance Mission composed of experts representing electricity undertakings in the various O.E.E.C. countries, was sent to the United States. In order to assess the results achieved a further study was organised in May 1956 to give its American and European members a general idea of the progress made in the field of production and transmission of electricity in Europe. On technical grounds they emphasised the need to prepare long term international development programmes to make the fullest possible use of thermal and hydro resources. This report gives their detailed findings.

Industrial Uses of Nitrogen in the United States
1957, 136 pp., 13s.

WORLD PRODUCTION of nitrogen at present tends to rise faster than consumption. This led the Chemical Products Committee of the O.E.E.C. to recommend a study of the possibilities of increasing the uses of nitrogen in the chemical industry. As the proportion of nitrogen consumed in the chemical industry is higher in the United States than in Europe, it was naturally of interest to study the situation across the Atlantic.

Part I of the report of the mission which visited the United States at the end of 1956 sums up the situation, in that country and in certain countries of Europe, as regards the production, marketing and consumption of nitrogen both as a fertiliser and in the chemical industry.

Part II, which is the more important, gives a detailed description of the characteristics and possible uses of a large number of nitrogen products.

The report is therefore a most valuable reference document for all who are interested in the commercial development of nitrogen and the uses of nitrogen products.

Oilseeds
1957, 336 pp., 24s.

SINCE 1938, there have been radical changes in the world pattern of production, trade and use of oils and fats. However, O.E.E.C. member countries have continued to be major net importers, taking quantities which have changed little in total since before the war. The bulk of their imports comes from the dollar area and from the tropical areas with which certain member countries have special relations (the overseas territories). Many of these territories are major producers, particularly of ground nuts, oil-palm products (palm oil and palm kernels) and of the products of the coconut palm (copra and coconut oil).

The report of the O.E.E.C. Overseas Territories Committee sets out a wide range of information on production of oils and fats, trade patterns, uses and prices. On the basis of this factual material, the report examines the possibilities of increasing production in the overseas territories of member countries, and method of achieving it.

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CALCULATION OF TERMINAL FALLING VELOCITY OF PARTICLES IN FLUIDS

A rapid method is given for calculating the rate of fall of particles in fluids (over a wide range of Reynolds numbers) without the need to apply techniques of successive approximation

by RENÉ JOTTRAND*

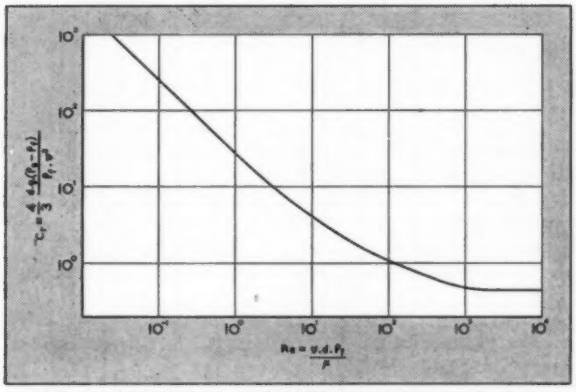

Fig. 1. Variation of coefficient of resistance C_r as a function of Reynolds number.

IN the classical method of calculating the terminal falling velocity of a spherical particle of diameter d in a fluid, in general one refers to a graph representing the variation of a coefficient of resistance C_r as a function of Reynolds number Re. These well-known graphs have the form shown in Fig. 1. They have a certain analogy with those which are used to determine the pressure drop in a pipe. These graphs are found in all the treatises of chemical engineering.[1, 2, 3, 4]

This method presents the following inconvenience. The two principal variables, that is to say the diameter and the terminal falling velocity occur simultaneously in the two co-ordinates. In a practical problem one of these two variables in general constitutes the unknown. One is therefore obliged to proceed by successive approximation or to use analytical expressions representing the experimental curve in a given region.

These analytical expressions are as follows:

(a) For small values of Re where $Re < 1$, Stokes law is valid.

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Symbols

d = particle diameter;
d_o = reference diameter;
g = acceleration due to gravity;
v = terminal falling velocity of the particle;
v_o = reference velocity;
μ = fluid dynamic viscosity;
ν = fluid kinematic viscosity;
ρ_f = density of fluid;
ρ_s = density of solid;
C_r = coefficient of resistance;
D_r = reduced diameter;
Re = Reynolds Number; and
V_r = reduced velocity.

$$v = \frac{g\,(\rho_s - \rho_f)\,d^2}{18\mu}$$

(b) For large values of Re where $Re > 1000$, Newton's law is valid.

$$v^2 = \frac{3g\,(\rho_s - \rho_f)\,d}{\rho_f}$$

(c) In the intermediate region $1 < Re < 1000$, one can use the approximate Allen's law.

$$v = 0.24\,\frac{[g(\rho_s - \rho_f)]^{\frac{2}{3}}}{\mu^{\frac{1}{3}}\,\rho_f^{\frac{1}{3}}}\,.\,d$$

The defect is therefore twofold: (1) it is necessary to have recourse to successive approximations; and (2) in replacing the experimental curve by an approximate analytical expression, an error is introduced mainly in the intermediate region.

Different calculating procedures have been proposed[1, 2, 3, 4] to avoid these difficulties. Nevertheless, one must regret their too-abstract character and the length of the necessary calculations. Below a method is presented which seeks to avoid these shortcomings.

Using the dimensionless quantities

same as $C_r = \frac{4}{3} \cdot \frac{d.g\,(\rho_s - \rho_f)}{\rho_f . v^2}$ and $Re = \frac{v.d.\rho_f}{\mu}$

two new dimensionless variables can be obtained. These are:

$$V_r = \left(\frac{Re}{C_r}\right)^{\frac{1}{3}} \text{ and } D_r = (C_r.Re^2)^{\frac{1}{3}}$$

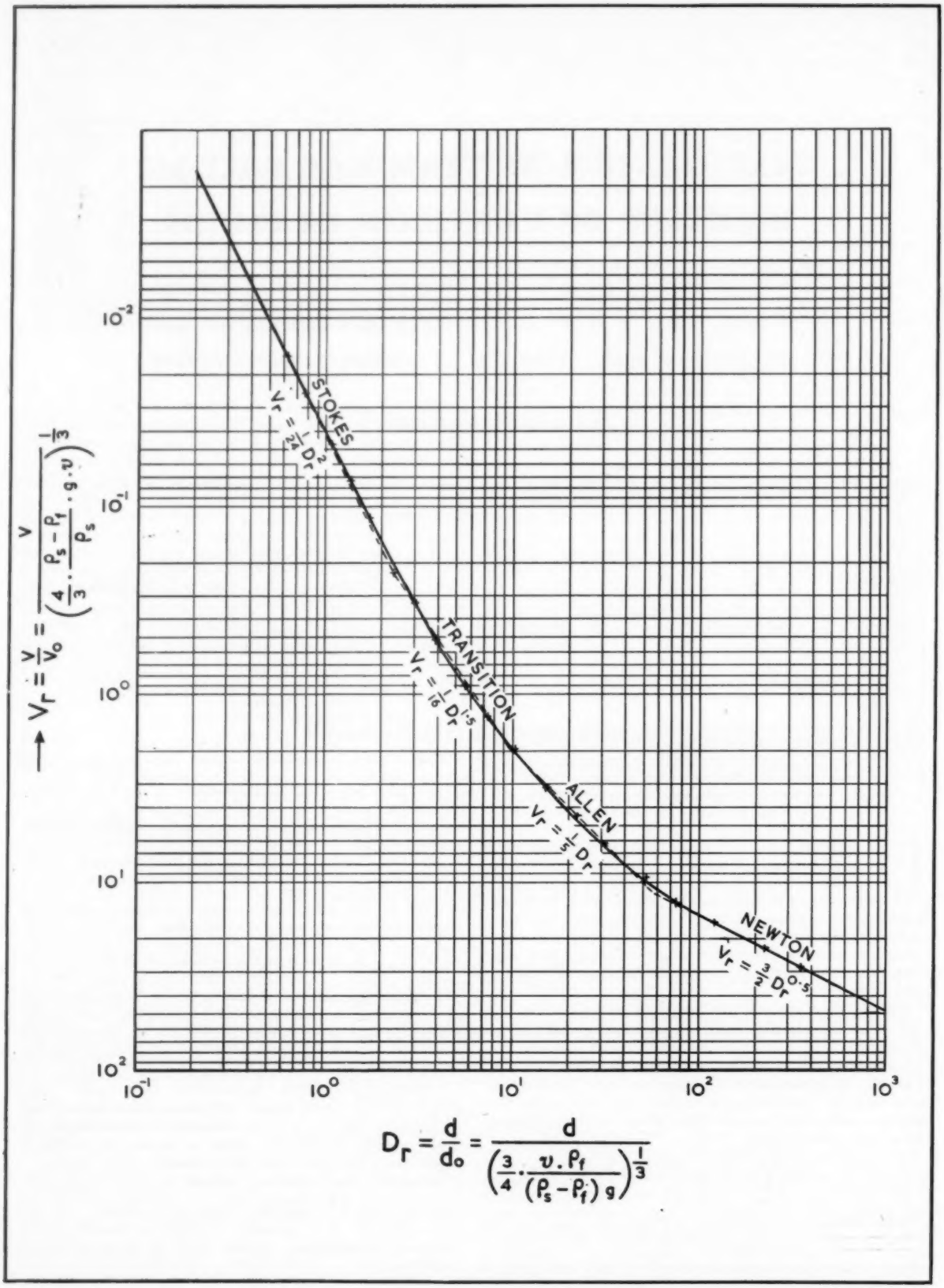

Fig. 2. Relation between the reduced velocity V_r and the reduced diameter D_r.

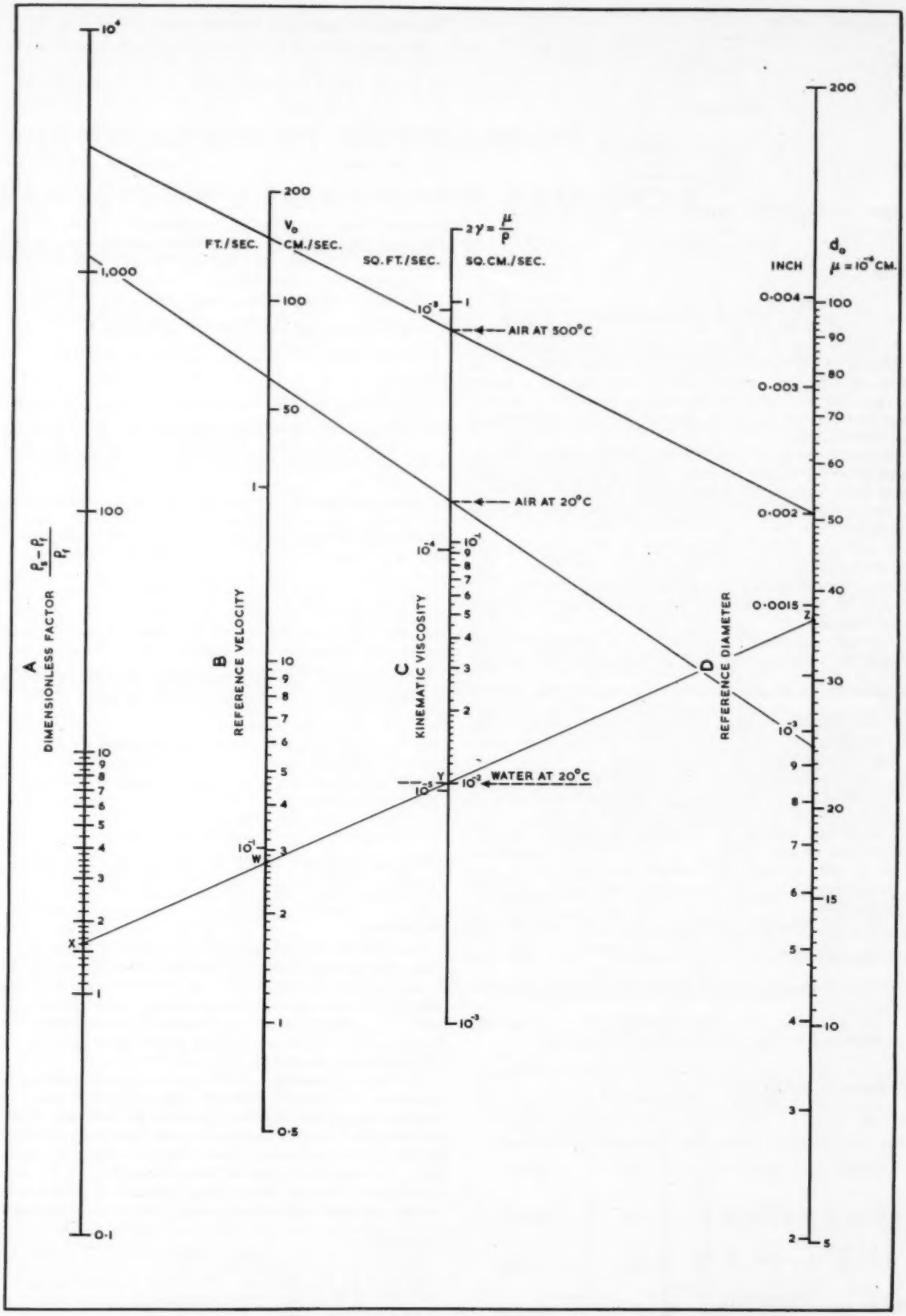

Fig. 3. Nomogram for the rapid calculation of the reference velocity and diameter v_0 and d_0.

or
$$V_r = \frac{v}{\left(\frac{4}{3} \cdot \frac{\rho_s - \rho_f}{\rho_f} \cdot g\, \upsilon\right)^{\frac{1}{2}}}$$

in which $\upsilon = \frac{\mu}{\rho}$

and
$$D_r = \frac{d}{\left(\frac{3}{4} \cdot \frac{\upsilon^2 \cdot \rho_f}{(\rho_s - \rho_f) \cdot g}\right)^{\frac{1}{3}}}$$

This can be further written

$$V_r = \frac{v}{v_o} \text{ and } D_r = \frac{d}{d_o}$$

where

$$v_o = \left(\frac{4}{3} \cdot \frac{\rho_s - \rho_f}{\rho_f} \cdot g\, \upsilon\right)^{\frac{1}{2}} \text{ and } d_o = \left(\frac{3}{4} \cdot \frac{\upsilon^2 \cdot \rho_f}{(\rho_s - \rho_f)\, g}\right)^{\frac{1}{3}}$$

It can be seen that V_r is a dimensionless quantity proportional to the velocity of fall and independent of the diameter. One can consider that it is a reduced velocity representing the ratio of the falling velocity, v, to the reference velocity v_o, which depends only on the densities and the viscosity.

Similarly, D_r is proportional to the diameter and independent of the falling velocity v. It is a reduced diameter equal to the ratio of the diameter d to a reference diameter d_o which also depends only on the densities and the viscosity.

If one plots V_r as a function of D_r, from the data in the literature about C_z as a function of Re (Fig. 2), the problem of calculating the terminal falling velocity of a particle of known diameter can be resolved in a very simple manner.

First one calculates the values of the reference velocity v_o and the reference diameter d_o. Secondly, the reduced diameter is calculated from $Dr = \frac{d}{d_o}$ Thirdly, the value of V_r corresponding to D_r is obtained from the graph (Fig. 2). Fourthly, one calculates the falling velocity $v = v_o\, V_r$.

The following points may be noted:

(1) The calculation of the effective diameter of a particle of which one knows the terminal velocity can be carried out in an absolutely analogous manner.

(2) If one studies the behaviour of different size distributions of one substance in one fluid, the calculation of v_o and d_o need be carried out once only. The remainder of the calculation can then be carried out immediately.

(3) The reference quantities v_o and d_o depend only on the two factors $g \cdot \frac{\rho_s - \rho_f}{\rho_f}$ and $\upsilon = \frac{\mu}{\rho_f}$: it is very easy to set up a nomogram which allows this to be calculated (see Fig. 3).

(4) The whole of the experimental curve is well represented by the following four expressions:

Range of Values for		Equation for	
V_r	D_r	V_r	Law
<0.24	<2.4	$\frac{1}{24} \cdot D_r^2$	Stokes
0.24 to 2	2.4 to 10	$\frac{1}{16} \cdot D_r^{\frac{3}{2}}$	Transition
2 to 12	10 to 60	$\frac{1}{5} \cdot D_r$	Allen
12 to 60	60 to 1600	$\frac{3}{2} \cdot D_r^{\frac{1}{2}}$	Newton

Description and Use of Nomogram (see Fig. 3)

The nomogram in Fig. 3 comprises four parallel scales "A", "B", "C" and "D", of which the successive spacings are in the ratio 1:1:2. The scales are all logarithmic and the moduli in the ratio $\frac{1}{2}:\frac{1}{2}:\frac{1}{3}:1$. On scale "A" we put the factor $\frac{\rho_s - \rho_f}{\rho_f}$ or $\frac{\rho_s}{\rho_f} - 1$. This factor is dimensionless and, therefore, independent of the units chosen. On scale "C" we put the kinematic viscosity of the fluid $\upsilon = \frac{\mu}{\rho_f}$: the scale is graduated both in sq. cm/sec. (or Stokes) and in sq. ft./sec. The scale "B" represents the reference velocity v_o in cm/sec. and in ft/sec. The scale "D" represents the reference diameter d_o in microns (μ) and in inches.

The points corresponding to $d_o = 100\mu$, $\upsilon = 1$ sq.cm/sec., $v_o = 100$ cm/sec. and $\frac{\rho_s - \rho_f}{\rho_f} = 765$ are aligned.

Examples

(1) Calculate the velocity of fall of a particle of density $\rho_s = 2.6$ g/cu. cm of effective diameter $d = 363\ \mu$ in water at 20°C. One obtains $\frac{\rho_s - \rho_f}{\rho_f} = \frac{2.6 - 1}{1} = 1.6$, which locates the point X. Then $\upsilon = \frac{\mu}{\rho_f} = 10^{-2}$ sq. cm/sec., which gives the point Y. On joining points X and Y, the intercept at Z gives $d_o = 36.3\mu$, and at W $v_o = 2.75$ cm/sec. or 0.09 ft/sec.

$$D_r = \frac{d}{d_o} = \frac{363}{36.3} = 10$$

From Fig. 2 the corresponding value of $V_r = 2$; then $v = V_r v_o = 5.5$ cm/sec. or 0.18 ft/sec.

(2) To calculate the effective diameter of carbon particles of density 1.4 if their terminal falling rate in air at 500°C is 0.01 ft/sec.

$$\frac{\rho_s - \rho_f}{\rho_f} = 3.060 \qquad \upsilon = 0.755 \text{ sq. cm/sec.}$$

The nomogram gives $v_o = 4.76$ ft/sec. $d_o = 52\mu$ or 2.04×10^{-3} in.

$$V_r = \frac{v}{v_o} = \frac{10^{-2}}{4.76} = 2.1 \times 10^{-3}$$

The corresponding value of $D_r = 0.225$ Then $d = D_r$. $d_o = 0.46 \times 10^{-3}$ in. $= 11.7\mu$.

Summary

The calculation comprises two parts:

(1) The determination of the two reference quantities v_o and d_o which depend only on the nature of the solid and of the fluid employed. For particles of a particular solid falling in a given fluid it is only necessary to perform one calculation of v_o and d_o. This is readily given by the use of the nomogram in Fig. 3.

(2) The comparison of the given experimental value (diameter or velocity) with the corresponding reference quantity allows the reduced values to be obtained. These are correlated by a single and general relation represented by Fig. 2. The unknown is then directly derived by calculating the product of the reference quantity and the corresponding reduced value. This method is rapid and precise and avoids all successive approximation procedures.

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66.051.4; 669.82; 621.039

THE SEPARATION OF URANIUM AND PLUTONIUM FROM FISSION PRODUCTS BY TRIBUTYL PHOSPHATE

Extract from a paper* by J. T. Wood, Ph.D., and J. A. Williams, B.Sc., A.M.I.Chem.E., on computing the performance of a multi-component solvent extraction system

URANIUM fuel discharged from a nuclear reactor contains uranium, plutonium and a large number of radioactive fission product elements, with mass numbers ranging from 72 to 155. In recovering the uranium and plutonium for further use, it is necessary to separate them not only from one another, but also from the radioactive contaminants. Criteria for a separation process have been outlined by Nicholls,[1] who has pointed out the very high degrees to which both recovery of fissile material and decontamination from fission products must be effected.

Of the solvent extraction processes described in the literature, those using tributyl phosphate (TBP) are the best documented. Advantages of this solvent include its very low mutual solubility with an aqueous phase, and its high selectivity for uranyl and plutonyl nitrates, which it extracts as undissociated molecules.

In the first extractor which is common to all published flowsheets it is desired to extract both uranium and plutonium into the solvent with very high efficiency, leaving in the aqueous phase as high a proportion of the fission product activity as is practicable. A centre-fed counter-current extractor is used, as illustrated in Fig. 1. The feed, obtained by dissolution of the fuel and containing an excess of nitric acid, enters the central region, solvent being introduced at one end, and a solution of nitric acid, known as the "strip", at the other. The purpose of the strip is to reduce progressively the amount of fission product activity carried in the solvent stream.

The paper considers as solvent a 20% v/v solution of TBP in "odourless kerosene" (aromatic-free), referred to hereafter as 20% TBP/OK.

The paper goes on to discuss detailed equilibrium partition data between the aqueous phase and 20% TBP/OK, then sets out the general considerations in the choice of operating conditions. Finally, the authors turn to detailed calculations.

The number of process variables is so large that the above observations still leave a wide range of feasible operating conditions, and detailed calculations are of great value in further reducing this range. Particularly in the cases of plutonium and fission products, undesirable conditions often become apparent only when detailed calculations are carried out. Calculations may thus be used to check that any given set of conditions should give a satisfactory performance of the extractor, and may be extended in order to find the particular set of conditions giving the best balance of uranium and plutonium extraction with fission product decontamination in a particular piece of equipment or the conditions requiring the minimum total of stages for a desired level of performance.

It is apparent that the distributions of uranium and nitric acid along the extractor are interdependent, and thus can only be established by trial and error. Plutonium and the fission products are governed in their behaviour by the distributions of uranium and nitric acid, but their own concentrations are so small that any effect they may have on the partition of uranium and nitric acid, or of one another, is negligible. The distributions of uranium and nitric acid must therefore be derived first, and this can be done without need for consideration of any other component. Using the results, the distributions of plutonium and of any fission product may then be calculated separately.

The concentrations of both uranium and nitric acid both vary considerably along the extractor. For this reason, the assumption, in any calculation, of constant acidity or constant partition cofficient can lead to considerable error, and stagewise calculation, using partition data appropriate to each stage, is essential.

Volume Changes

Although the two phases are almost completely immiscible, changes in the volumes of both phases, of the order of 5%, do occur, mainly as a result of the transfer of uranium from the acqueous feed to the solvent. Since

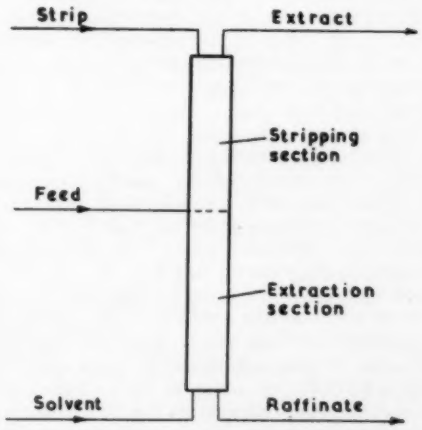

Fig. 1. Centre-fed counter-current extractor.

* *Computation of the performance of a multi-component solvent extraction system. The separation of uranium and plutonium from fission products by tributyl phosphate. This paper formed part of a symposium on Nuclear Energy organised by the British Nuclear Energy Conference and sponsored by the Institution of Chemical Engineers.*

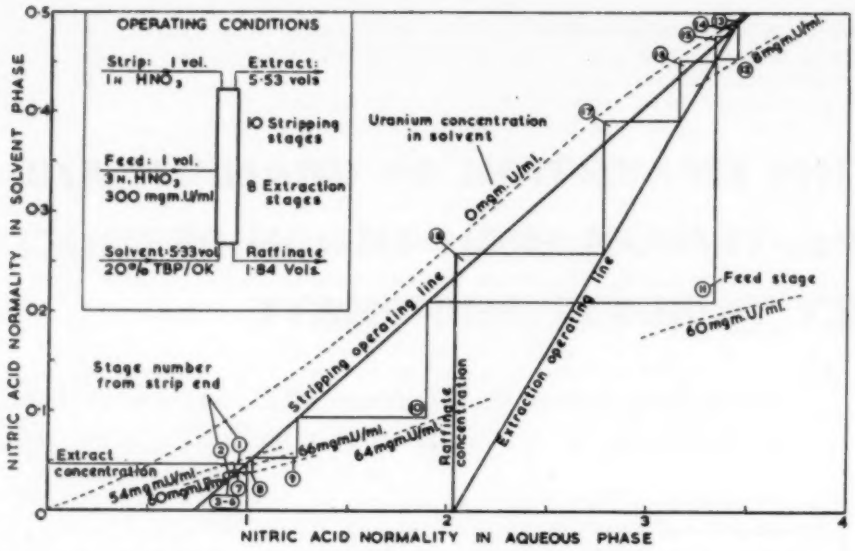

Fig. 15. Plot of nitric acid concentrations for conditions shown.

most of this transfer takes place at the feed stage, the effective flow ratios may be based on the volumes of the strip (feed) and extract in the stripping section, and of the raffinate and solvent (feed) in the extraction section. The error introduced is negligible except at the feed stage itself, but it is worth noting that the corrected operating lines now intersect not at the feed concentration, but at a slightly higher value.

Stage Efficiency

One of the greatest difficulties is in calculating the stage efficiency. The stage concept is applicable to mixer-settlers, the stage efficiencies of which are high, but less than 100%. The use of theoretical stages in calculation, coupled with an overall stage efficiency, is unsatisfactory since the overall efficiency depends upon the partition coefficient and thus varies for different components. In addition, it is necessary to define the concentrations of uranium and nitric acid in each stage in order to calculate the concentrations of other components, and this can be done by calculation on the basis of practical stages.

It is unfortunately impossible at present accurately to predict the stage efficiency for any component in any stage. Of the several alternative definitions of stage efficiency, the method preferred is to apply a factor to the concentrations in whichever phase represents the higher value of efficiency. Thus the factor is applied to the solvent phase when the partition cofficient is lower than the aqueous/solvent ratio. In all cases the actual change in concentration in the phase is assumed to be 95% of the theoretical change, this value giving the best general agreement between calculated stage concentrations and those measured in the type of mixer-settler used.[13]

Calculation of Uranium and Nitric Acid Distribution

The first step in calculation, for a given combination of variables (feed and strip compositions, flowrates, and number of extraction and stripping stages), is to estimate the aqueous nitric acid distribution. The second step is to plot an operating diagram for uranium, the operating lines being fixed in the first instance by assuming the concentration of uranium in the raffinate to be negligible, the extract concentration then being given by mass balance. Starting at the extract concentration, steps are drawn as previously described, but using in each stage a uranium equilibrium line interpolated from Fig. 3† for the particular value of acidity estimated for that stage. The stage efficiency is applied to each stage in turn. In most cases the plot need only be extended to the first stage beyond the feed stage, as the uranium concentration in the solvent phase is thereafter usually below 1 mg U/ml, and does not affect the nitric acid distribution.

The distribution of nitric acid may now be calculated more accurately, using Fig. 4† and the calculated values of uranium concentration. A second graph of uranium concentrations is then plotted, and the process repeated until agreement is reached between successive diagrams. The calculation of the nitric acid distribution is more complicated than is the case for uranium, since nitric acid is present in both aqueous feeds, and in significant amounts in both extract and raffinate. Thus the operating lines cannot be established except by an iterative method. The extract concentration is first estimated, and a corresponding raffinate concentration found by mass balance. A stagewise calculation is then carried out from the raffinate end, using partition data corresponding with the calculated uranium concentrations, giving eventually a calculated value for the extract concentration. If this does not agree with the figure assumed, then a new value must be estimated, and the operation repeated until agreement is reached. It is often found quicker, and more accurate, to follow this procedure by an arithmetical method of calculation.

Typical results of calculations are shown in Figs. 15 and 16, for nitric acid and uranium respectively, with a 3N feed, 1N strip, and other conditions as shown in Fig. 15. Fig. 15 shows that the aqueous acidity is constant over much of the stripping section, at a value slightly below that of the strip, and then rises sharply towards the feed stage. Build-up of nitric acid, to a concentration higher than that in either of the acid feeds, as shown in Fig. 15, is a very common result. Exceptions to this behaviour arise only when the difference between the acidities of the two feeds is large. Thus in the simplified diagram Fig. 17, the acidity of the strip is appreciably higher than that of the feed. In this case, assuming no volume changes, the operating lines meet at the feed concentration at a point outside the diagram; the acidity at the feed stage lies between those of the feed and strip, and the steps proceed along the stripping section in the opposite direction to that in Fig. 15.

As a result of acid build-up, the uranium pinch in Fig. 16 occurs not at the feed stage, as in Fig 9,† but at M, roughly in the centre of the stripping section. In fact M represents a composite pinch for both uranium and nitric

† *For figures so marked, refer to original paper.*

acid, at which the concentration of uranium in each phase is a maximum, and the number of stripping stages, if greater than that shown, has no effect on the concentration at the feed stage. In calculations for conditions in which the number of stripping stages is initially unknown, it is wise to assume sufficient stages to give such a pinch.

The distributions of uranium and nitric acid having been established, it is possible to calculate that of any other component for which relevant partition data are available, and in addition it is possible to extend the uranium plot along the extraction section. It is normally desired to calculate either the raffinate concentration which will be obtained with a given number of extraction stages, or the number of stages required to give a desired concentration. In the latter case the calculation is straightforward, as the extraction operating line is fixed, and steps may be drawn simply. In the former case the operating line must be established by trial and error, but in both cases the raffinate concentration should be so low as to involve negligible error in the stripping operating line assumed in the initial calculations.

Calculations of uranium concentrations may be carried out graphically or, if the raffinate concentration is known, by use of the expression

$$C_n = \frac{C_{n-1} + C_R \dfrac{\xi}{100} \cdot \dfrac{R_e}{K_{n-1}}}{1 - \dfrac{\xi}{100}\left(1 - \dfrac{R_e}{K_{n-1}}\right)}$$

where C_n and C_{n-1} are the aqueous concentrations in adjacent stages numbered from the raffinate end, C_R is the raffinate concentration, R_e the extraction flow ratio, K_{n-1} the partition coefficient of uranium in stage $n-1$, and ξ the percentage stage efficiency, applied to the aqueous phase. This expression shows that as the value of R_e/K_{n-1} is normally very low, in the range 0.01—0.05, a stage efficiency of 95% is the most important factor in determining the practical extraction factor, C_n/C_{n-1}. As a result, the relation between the overall extraction efficiency and the number of extraction stages varies little with the operating conditions, provided that both aqueous feeds have an acidity greater than 1N.

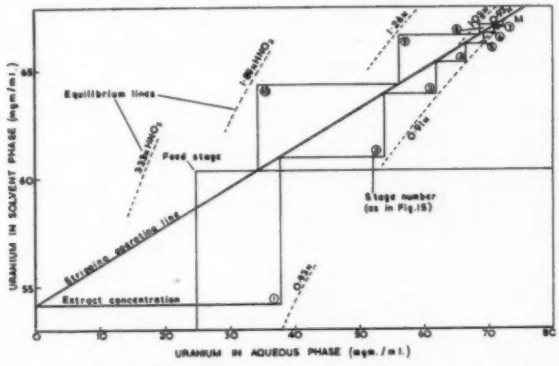

Fig. 16. Uranium concentrations in stripping sections (conditions as for Fig. 15).

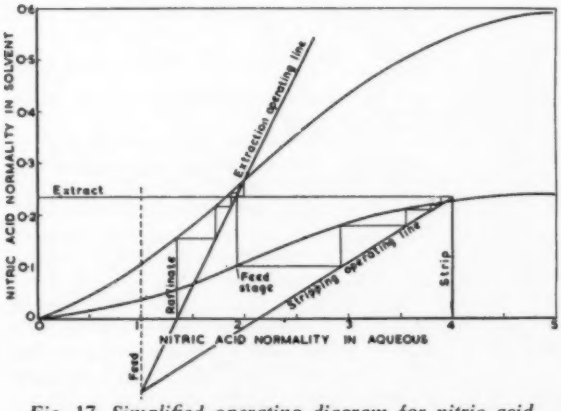

Fig. 17. Simplified operating diagram for nitric acid showing effect of wide difference in strip and feed acidities.

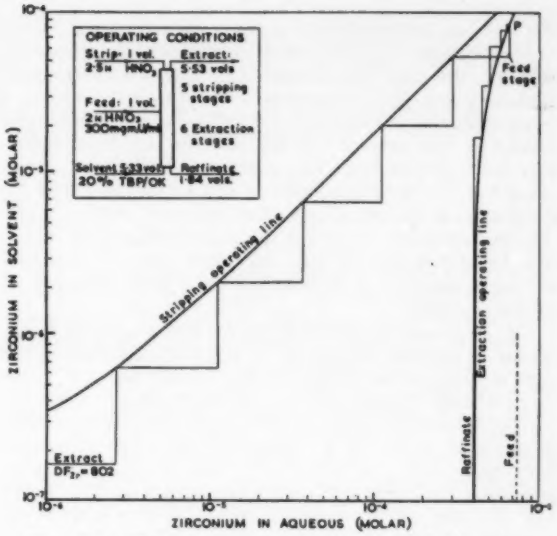

Fig. 18. Zirconium operating diagram (showing pinch).

Calculation of Plutonium Distributions

Once the distributions of uranium and nitric acid have been established for a particular set of conditions, the concentrations of plutonium in the stripping section and feed stage may easily be calculated, using the graphical method and partition data from Fig. 6.† Under all correctly chosen conditions a composite pinch should be formed or approached, usually in the central region of the stripping section, at which the concentrations of uranium, plutonium and nitric acid are all constant. Calculations for the extraction section are complicated by the presence of the three valency states, and should ideally take account of the kinetics of re-equilibration, when the equilibrium is disturbed by the preferential extraction of Pu(iv). Rates for this process in an extractor are not available, but Pu(iii) is known to be unstable under the prevailing conditions,[21] and Pu(vi) to be relatively stable. The method of calculation adopted is to assume that the proportion of Pu(iii) is kept low in all stages by oxidation, and to use partition data for Pu(vi). The relation between raffinate concentration and number of extraction stages may then be established either by the graphical or arithmetic method, as for uranium. Since the stage efficiency is again dominant in determining the extraction factor, the difference in result between calculations using Pu(vi) and Pu(iv) partition data is relatively small.

Calculation of Zirconium and Ruthenium Distributions

In dealing with fission products it is customary to employ a term called the decontamination factor or DF, which is defined as the ratio of fission product activity per unit weight of uranium in the feed to that in the extract. The term may be related either to a group of fission pro-

ducts or to an individual, using a subscript, e.g., DF_{Zr}.

Fig 18 shows a typical operating diagram for zirconium, drawn in this case for a 2N feed, 2.5N strip, and other conditions as shown. Such a diagram is drawn by first assuming a large value of DF_{Zr} and thus obtaining the raffinate concentration by mass balance with the feed. The extraction operating line is drawn from its equation and steps are drawn using Fig. 7,† from the raffinate end to the feed stage. A finite extract concentration is then assumed, and a corresponding stripping operating line constructed, this operation being repeated by trial and error until the assumed extract concentration is reached in a given number of stripping stages.

Fig. 18 shows a pinch P in the extraction section, in the region of constant acidity (cf. Fig. 15). It is desirable that such a pinch, which maintains the concentration at a low value, should be obtained for all fission products. In the case of zirconium, high acidity in the extraction section, giving high values of K_{Zr} (Fig. 7†), can lead to serious build-up of this component, as shown in Fig. 19. Fig. 19 assumes a 5N feed, with other conditions exactly as for Fig. 18. Although the stripping section is apparently effective, DF_{Zr} is very much smaller than in Fig. 18.

Figs. 7† and 8† show that the values of K_{Zr} and K_{Ru} are affected in opposite senses by the acidity, and for overall decontamination there is clearly an optimum value of acidity. Since the acidity is never constant along the extractor, the optimum combination of acid feeds can only be established by calculations over a range of conditions. Fig. 20 shows the effect on DF_{Zr} and DF_{Ru} of the strip acidity, with a 2N feed, and other conditions as shown. The overall decontamination factor DF_{Zr+Ru}, calculated for a ratio $Zr/Ru = 2/1$ in the feed, shows a well-defined maximum at a strip acidity of 2.4N, a value which applies, however, only to the given combination of other variables.

Final Choice of Operating Conditions

By repeating calculations for different combinations of the variables, it is possible to evaluate the range of operating conditions which can give a required level of performance, though the optimum conditions can only be established by economic considerations. Calculations may in addition be extended to investigate the relative stability of different sets of conditions. Calculations can be of great value in checking that a stable system is being operated in existing equipment. Similarly, in designing new plant, it is possible to calculate the number of stages required to give a minimum required performance even if the worst combination of probable deviations from control conditions should occur during plant operation. Such considerations must influence the final choice of operating conditions.

The Limitations of Calculation

Whilst the broad outlines of a process can be calculated by the means described in this paper, it must be emphasised that a reliable prediction of performance can only be made when all the partition data required are available. Where there are several compounds of an element in equilibrium, as occurs for example with plutonium and ruthenium, then kinetic data may have to be considered in addition to normal partition data; in such cases it is sometimes more satisfactory in the present state of knowledge to obtain detailed information by experiment under conditions closely approximating, with respect to time of residence and flow ratios, to those of the plant.

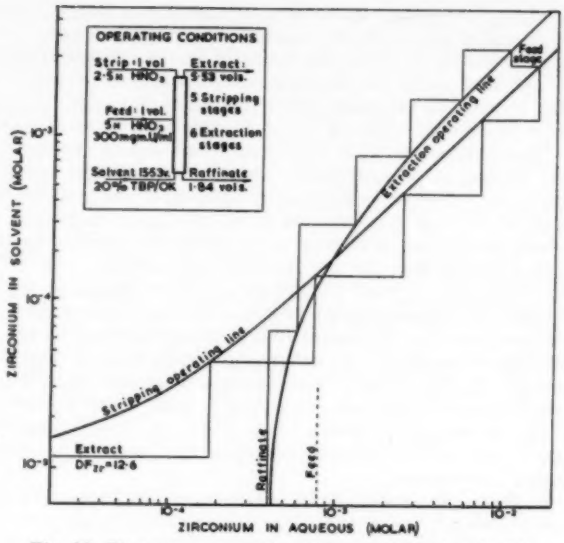

Fig. 19. Zirconium operating diagram (showing build-up).

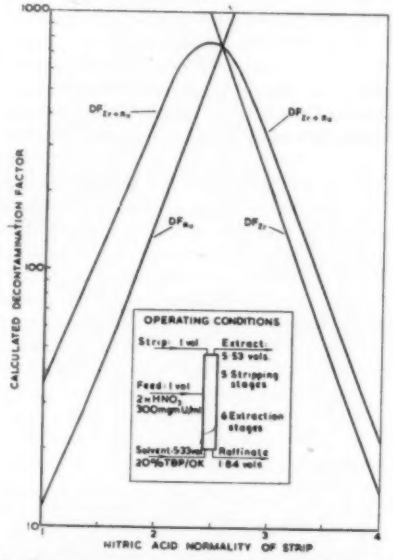

Fig. 20. Optimum strip acidity (for conditions shown).

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EXHIBITIONS, CONFERENCES AND SYMPOSIA

DIARY FOR 1958

Home

March 24. *Physical Society Exhibition,* Royal Horticultural Society's Hall, until March 27. Details from the Secretary, The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

March 24. *Fourth International Instrument Show,* Caxton Hall, London, S.W.1, until March 29. Details from B & K Laboratories Ltd., 57 Union Street, London, S.E.1.

March 25. Institute of Mechanical Engineers Conference, *Technology of Engineering Manufacture,* until March 27. Details from the Secretary, The Institute of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

March 25. *Electrical Engineers' Exhibition,* Earl's Court, London, until March 29. Details from Press Officer, Exhibition Press Office, 79 Leghorn Road, London, N.W.10.

April 10. *F.B.I. Conference on Nuclear Energy,* Eastbourne, until April 12. Details from the Conference Secretary, Federation of British Industries, 21 Tothill Street, London, S.W.1.

April 16. *Instruments, Electronics and Automation Exhibition,* Olympia, London, until April 25. Details from Industrial Exhibitions Ltd., 9 Argyll Street, London, W.1.

May 7. *Mechanical Handling Exhibition and Materials Handling Convention,* Earls Court, London, until May 17. Details from Press Officer, Associated Iliffe Press, Dorset House, Stamford Street, London, S.E.1.

May 12. *The Production Exhibition,* Olympia Grand Hall, London, until May 21. Details from Press Officer, 32 Millbank, London, S.W.1.

June 18. *Chemical and Petroleum Engineering Exhibition,* Olympia, London, until June 28. Details from the Secretary, The Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

June 24. Institution of Chemical Engineers' Symposium on the *Organisation of Chemical Engineering Projects,* Olympia, London, until June 26.

July 21. *International High-Polymer Conference,* Nottingham, until July 24.

November 6. *Scientific Instrument Manufacturers' Association* 1958 *Convention,* Majestic Hotel, Harrogate, until November 9. Details from S.I.M.A., 20 Queen Anne Street, London, W.1.

Overseas

March 2. *Leipzig Fair* until March 11. Details from Leipzig Fair Agency, Dept. D4, 127 Oxford Street, London, W.1.

March 17. *Annual Conference—National Association of Corrosion Engineers,* San Francisco, California, until March 21. Details from National Association of Corrosion Engineers, Southern Standard Buildings, Houston, 2, Texas.

April 12. *Japan's International Trade Fair,* Osaka, until April 27. Details from Japan International Trade Fair Commission, Honnachibashi, Higashi-Ku, Osaka.

April 14. *Third Design Engineering Show,* Chicago, until April 17. Details from Clapp & Poliak Inc., 341 Madison Avenue, New York, 17, U.S.A.

April 17. *Brussels World Exhibition* until October 19. Details from Commissariat-General of the Government for the Brussels Universal and International Exhibition, 1958, 28 Putterie, Brussels.

April 28. *Meeting of the Conference of the Engineering Societies of Western Europe and the United States of America* (E.U.S.E.C.) until May 2, in New York. Details from Secretary, The American Society of Mechanical Engineers, 29 West 39 Street, New York, 18, U.S.A.

May 10. *Tenth Liège International Fair,* Belgium, until May 26. Details from U.K. Representative, R. C. Liebman, 178 Fleet Street, London, E.C.4.

May 24. *Fourth Congress of International Water Supply Association,* Brussels, Belgium, until May 31. Details from Mr. L. Millis, International Water Supply Association, 34 Park Street, London, W.1.

May 31. *Achema* 1958 *Exhibition and Congress of Chemical Engineering,* Frankfurt (Main), Germany, until June 8. Details Deutsche Gesellschaft für Chemisches Apparaatewesen E.V. Frankfurt (Main), Germany.

June 2. *Symposium on Peaceful Uses of Atomic Energy,* Sydney, Australia, until June 6. Details from the Symposium Secretary, A.A.E.C. Research Establishment, Private Mail Bag, Sutherland, New South Wales, Australia.

June 8. *Poznan International Trade Fair* until June 22. Details from Poznan International Fair, 14 Glogowska Street, Poznan.

June 9. *International Automation Congress and Fourth International Automation Exposition,* New York, U.S.A., until June 13. Details from Richard Rimbach Associates Management, 845 Ridge Avenue, Pittsburgh, 12, Pennsylvania.

June 25. *International Institute of Welding—Annual Assembly,* Brussels, Belgium, until July 1. Details from International Institute of Welding, 2 Buckingham Palace Gardens, London, S.W.1.

July 14. *Sydney Engineering Exhibition of* 1958, until July 19. Details from The Industrial Public Relations Service of Australia, Box 4962, G.P.O., Sydney.

September 8. *International Pharmaceutical Federation, Seventeenth General Assembly and Eighteenth International Congress of Pharmaceutical Sciences,* Brussels, Belgium, until September 15. Details from International Pharmaceutical Federation, c/o Dr. J. W. Birza, 196 Bilderdijkstraat, Amsterdam, W. Netherlands.

September 10. *First International Meeting on Coal Petrology,* Brussels, Belgium, until September 13. Details from Secretary of the Committee on Coal Petrology, Geoligsch Bureau, Akerstraat 86-88, Heerlen.

September 15. *International Congress on Ceramics,* Wiesbaden, Germany, until September 20. Details from Sekretariat des VI Internationalen Keramischen Kongresses, Bonn/Rhein, Reuterstrasse 235, Germany.

September 22. *Seventh International Gas Congress,* International Gas Union, Rome, Italy, until September 25. Details from Mr. R. H. Touwaide, General Secretary, International Gas Union, 4 avenue Palmerston, Brussels, 4, Belgium.

December 26. *Annual Meeting, American Association for the Advancement of Science,* Washington, D.C., U.S.A., until 31. Details from Dr. Raymond L. Taylor, American Association for the Advancement of Science, 1515 Massachusetts Avenue N.W., Washington, 5, D.C., U.S.A.

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REVIEW OF 1957 LITERATURE*

CHEMICAL ASPECTS OF NUCLEAR REACTORS – PART I

A review of developments on nuclear fuel, fuel cycles and the disposal of radioactive waste

by J. BURKETT, F.L.A.

THE many applications of nuclear chemistry are dealt with by HAISSINSKY.[1] SPENCE gives an account[2] of some of the more striking new scientific advances made in the Chemical Division of the Atomic Energy Research Establishment at Harwell. PAINTER and HUFF have written an operating manual for the analytical control laboratory.[3] They briefly describe the theory and operational procedure of apparatus and materials used. They cover control laboratory operation, including safety, precision, records, dilution factors, warm laboratory equipment, remote apparatus and training.

MARTIN analyses the chemical and chemico-metallurgical problems involved in the choice and construction of fuel elements and considers some of the problems arising as a result of reactor operations.[4] The part played by ion-exchange in nuclear technology is described by ROLAND, who covers the extraction and purification of uranium, the treatment of reactor water, the purification of zirconium and the disposal of waste.[5]

Nuclear Fuels and Fuel Cycles

The fuel cycle is considered to be the most important factor in the achievement of economically-competitive nuclear power. A "Chemical Engineering Progress" symposium[6] includes discussions on fuel cycle evaluation; recovery of uranium from slag scrap and by solvent extraction of slurries; fission product removal; the preparation of fuel cladding and ceramic fuel elements; and the volume reduction of wastes.

The cost of fissile materials for different types of power reactor has been analysed. WEISSBARTH[7] shows that the homogeneous reactor, fed with highly-enriched U-235, requires the lowest capital investment in fissile material. In Sweden, the reactor programme which provides for six reactors for district heating and two for electric power generation will create a demand for enriched uranium that will outstrip production after 1961. SVENKE[8] discusses Swedish productive capacity for thorium, graphite, heavy water and zirconium and considers the efficiency and costs of fuel cycling.

HOLZER[9] estimates the cost of the nuclear fuel and total fuel inventory for the A.M.F. 22-MW closed-cycle boiling-water reactor. Given reasonable design objectives and economy in fabrication of fuel elements and reprocessing, the nuclear fuel would cost 0.707 mills/kWh of heat, i.e., 1.86 mills/kWh electrical.

LEWIS claims feasibility for a power reactor to operate on natural uranium with an energy yield of 10,000 Mwd/t without reprocessing. He considers a core of uranium or uranium dioxide fuel slugs lying in horizontal pressurized channels surrounded by heavy-water moderator and reflector. The average neutron flux is kept to 3×10^{13}. Assuming the cost of uranium is 40 dollars/kg, fuel supply cost is estimated at less than 0.7 mills/kWh.[10] MOORADIAN[11] supports the view that a heavy-water reactor appears to offer fuel costs low enough to compete with thermal power stations. The work at Chalk River on the NRX type of reactor has been encouraging, but a fuel more corrosion-resistant than uranium remains to be developed. A sintered compact of uranium oxide, however, has been produced on a laboratory scale. KASTEN and AVEN[12] have estimated fuel requirements of a heavy-water homogeneous power reactor for a variety of initial loadings. Both batch and continuous methods were used for fuel removal.

DAVISON and CLAYTON[13] found that significant power increments could be produced by small amounts of additional U-235 using a reactor with a flattened region and close rod spacing. Graphs and tables are presented showing radial distribution of thermal flux, enrichment, power per rod and U-235 to Pu-239 conversion ratio. Others include U-235 investment, power output and efficiency of utilisation of fissile material as functions of the radius of the flattened region.

BENEDICT and PIGFORD[14] investigated what fraction of fuel charged to a reactor may be caused to undergo fission

* *This review does not include material published by the* U.K.A.E.A.

Mr. Burkett *is in charge of the Information Section at Hawker Siddeley Nuclear Power Co. Ltd., having come from the Nuclear Division of Rolls-Royce Ltd. He has also been responsible for setting up information services at the Engine Laboratory of Associated Ethyl, the National Police College and the Ministry of Civil Aviation.*

before a reactor ceases to be critical. They consider the interrelationships between a nuclear reactor and the processing plants. The limiting factors in fuel utilisation in mixed-fuel reactors are discussed and flowsheets for uranium-plutonium fuel cycles together with fuel costs are given. They conclude with the treatment of single-region thermal breeders.

ROBB investigated the possibility of operating a light water-cooled and -moderated reactor with a fuel cycle using natural uranium feed and plutonium recycle.[15] Burn-up calculations for a continuously-fed heterogeneous reactor indicate feasibility, provided an alloy or oxide fuel is not required. CURTIS and others[16] employ physical methods of measurement in the determination of Pu-239 production to U-235 destruction in the Experimental Breeder Reactor.

The application of thorium to nuclear engineering is considered by BELL,[17] who outlines relevant physical, mechanical and chemical characteristics; in particular, the compatibility with other reactor materials. HOWE is also concerned with the properties of thorium and its alloys.[18] He describes the production of U-233 from thorium in such reactors as the SGR and the LMFR and includes the preparation of slurries and the refining of spent elements.

In a preliminary cost estimation for a thermal breeder reactor power station, ARNOLD and others[19] indicate that the chemical processing cost will be 1.06 mills/kWh of electricity, based on current Thorex technology for a limited-size plant. Unit fuel cost including reactor inventories, fuel consumption and losses, together with the chemical processing cost, is estimated at 2.19 mills/kWh(e) or 12.26 dollars per MW-day of heat. Other economic aspects of thorium breeder reactors are examined by CLAIBORNE and TOBIAS.[20] Some economic and nuclear characteristics of cylindrical thorium breeder reactors have been studied by HAMILTON and KASTEN, who report on breeding ratios, core-wall-power density and fuel costs as a function of reactor size for a given total power.[21] Thorium blanket systems which have been seriously considered are briefly described by LIETZKE and STOUGHTON,[22] who discuss the general considerations in the choice of type of breeder blanket. The advantages and problems of various chemical systems are outlined. A single-region spherical heterogeneous thorium breeder reactor containing U-233-Th rods moderated with heavy water was the basis of a study of fuel exposures. PRICE and JAYE[23] consider that, under certain assumptions, exposures of 10,000 Mwd/t and above can be achieved with retainment of the initial fuel inventory. Oak Ridge is developing a two-region homogeneous thorium breeder reactor. FERGUSON[24] outlines the scheme for chemical processing.

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Radioactive Waste Disposal

The hazardous waste created in nuclear power production affects the cost of the fuel cycle and the general environment. ARNOLD examines disposal problems including fission product utilisation, methods of shipping, the location of plant and disposal sites, potential danger to the public and third-party liability.[49] CULLER and MCLAIN[50] have made a comprehensive survey of waste-disposal techniques and report on requirements, costs, hazards and long-term considerations. ZEITLIN and others,[51] in studying the economics of waste disposal, estimate that by the year 2000 fission-product activity may have accumulated to a total amount greater than 13×10^{11} curies. They examine the problem of what proportion of the cost of nuclear power can be economically allocated to waste disposal. $1.60 to $1.64 a gallon is considered permissible for predicted nuclear power economics. They also consider the optimum waste-storage (cooling) period and shipment weight (including the shield) in relationship to minimum cost.

The disposal of radioactive effluents affects design and operation of nuclear power plants. FARMER reviews[52] the many aspects of this problem as it affected the Windscale works in the choice of piles, the chemical processes and siting. The manner in which waste disposal is to be handled at Dounreay is reported.[53] The dangers inherent in discharging radioactive wastes were the concern of an inquiry on the siting of Hunterston nuclear power station. Statutory safeguards were strongly recommended.[54]

A survey has been made by JOSEPH[55] of the extent of the disposal of radioactive wastes in the United States from 1946 to 1956. He summarises the types of packaging used and the places where the wastes were dumped.

The relationship of sanitary engineering to reactor waste disposal is discussed by TERRILL and HOLLIS. They take Shippingport as an applied example and discuss the principal considerations.[56] KENNY[57] examines the problems associated with the disposal of radioactive wastes to sewers and eventually into rivers. He discusses the general principles on which maximum permissible levels of irradiation are fixed, indicating that these levels are not exceeded with the present usage of radioisotopes. The contamination of drains and the hazards to workers at the sewage plant are considered together with the effect of radiation on sewage purifying organisms.

The expansion of the nuclear power programme will result in an enormous accumulation of dangerous radioactive wastes. AMPHLETT[58] outlines the various processes for converting the waste to solid form such as fixation by ion-exchange followed by firing; or combined calcination and ion-exchange or conversion to unleachable glasses, melts or ceramics. He favours the ceramic process. SEEDHOUSE[59] advocates a chemical flocculation process followed by ion-exchange in columns.

A preliminary report[60] has been made for the Atomic Energy Commission for the construction of a plant to treat the low-level radioactive liquid waste that will result from various laboratory processes. The cost has been estimated at $180,000.

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AMERICAN LETTER

Plant Control and the Chemical Engineer

AN important factor in any industrial process is plant control, and frequently it is the responsibility of the project engineer to specify the routine tests and control procedures to be used in the process, as well as the means for undertaking them. Accordingly, a knowledge of modern laboratory and test equipment is essential if full advantage is to be taken of recent developments in this field, which can lead to important savings in labour, materials and operating costs in the plant. The last New York Chemical Show emphasised this fact and it is felt that details of typical control apparatus now available in the U.S.A. will be of interest.

The high mortality of glassware used in plant tests can be offset in many cases by the use of modern plastics. For instance, a full range of high-temperature polyethylene laboratory ware is now available for use at temperatures up to 250°F; a half-litre conical filtering flask costing about $3.50. Thin-walled Teflon vessels which can be used continuously at 500°F offer many advantages and are priced at $13.00 for a 6-in.-diameter evaporating dish and $10.75 for a 250-ml beaker, to quote two examples. The cost per foot of thin-walled Teflon tubing, also inert to 500°F, ranges from about $0.85 to $9.35 for ¼-in. to 1-in. diameter tubing respectively. Another aid to the plant laboratory is a silicone-water concentrate used for "armour-cladding" glassware; this is claimed to defy scratching and is said to promote longevity at a cost of a penny for twenty pieces of glassware coated!

For titration tests, several improved devices are available, ranging from simple Teflon burette plugs to automatic titrators offering speed and accuracy. One recent development, a motor-operated piston burette, incorporates a micrometer, which gives an accuracy better than 0.1% of full capacity, down to 0.01 ml and should be ideal for fast control work by non-technical personnel. The trend towards the use of rapid micro methods is evident by the availability of a 7-ml bench-type "Ultra-Buret", which also incorporates piston displacement and a micrometer, enabling an estimation of 0.0001 ml to be made. The price for the complete unit is $265. A micro syringe-type burette, graduated in divisions of 0.0001 ml and with a capacity of 0.25 ml, costs $95.

Many types of moisture tester are now available for routine control purposes and are designed to ensure rapid drying as well as use by relatively unskilled personnel in the laboratory or plant. Several models employing infra-red heating as the drying medium are available and usually include a built-in precision weighing mechanism that enables rate-of-drying curves to be obtained as well. Drying times may be as low as five to ten minutes, so that close quality control can be maintained on a wide variety of materials, such as foodstuffs, pharmaceuticals and inorganic compounds. Typical of such equipment is the Aqua-Scale moisture tester, made by Analytical Measurements Inc., and the Ultra-Rapid Tester made by the Brabender Corporation. The latter company also sells a fully automatic moisture tester, which draws a sample every twelve minutes from a materials line in the plant, determines the free moisture gravimetrically to an accuracy of 0.1% and records the results. Such a device should offer considerable benefits to plants where moisture is a critical factor.

Control and Test Equipment

Since chemical engineers on both sides of the Atlantic are active in many industries other than chemical processing, some knowledge of control and testing equipment designed to replace subjective judgment is always advantageous. Present-day costs of many raw materials, processing and tightening quality control standards have in many cases made the foreman's thumb or eye alone an unreliable guide. Companies such as the Photovolt Corporation have developed a whole range of photometric equipment for the accurate routine determination of such factors as reflectance, opacity and colour; these instruments in many cases can be adapted either for use in the plant or as aids to routine quantitative analyses involving colorimetry, *pH*, partition chromatograhpy and paper electrophoresis. A typical instrument that has many applications both in research and control is the Photovolt self-generating Densitometer, selling at $258. Other instruments are available which are suitable for ultra-violet and fluorescent operation, while light values as low as 0.0001 micro-lumens can be measured if multipliers are used. The applications of infra-red absorption, gas and liquid chromatography to routine plant control are widely known and need no further mention.

One instrument that was initially developed for clinical use, but is finding increasing service in industrial processing fields, is the Auto-Analyser made by Technicon Inc. This apparatus continuously samples a plant stream and compares the desired component (which can be either a simple inorganic ion or a complex organic group) with a known standard under identical conditions. The important feature is that a ratio comparison is made instead of a lengthy end-point determination. A colour reaction is used to vary the light transmitted through a split-beam optical system, which in turn operates a recorder and a plant controller. The instrument sells from about $1500 upwards, according to application, and can yield large savings in the cost of labour, wasted materials and operating costs.

No review of modern control apparatus available to the project engineer would be complete without some reference to electronic data logging and plant computers. The present situation is somewhat Gilbertian, for undoubtedly there are many processes ripe for computer control and numerous types of computers are now available yet, to date, applications have been relatively few. This dilemma has been discussed in an interesting paper by E. M. GRABBE, which was presented at the Instrumentation and Control in the Process Industries Conference held in Chicago last year. The delay cannot be due to cost alone, for the price of a practical plant computer such as the Ramo-Wooldridge model RW30 (which has a 17-bit word length and an 8000-word memory) is but a fraction of the cost of an average-sized project, while the potential savings that would arise from a plant operating continuously at controlled maximum outputs under a variety of conditions would in many cases reduce the cost of a suitable computer to very small proportions. Major reason for the delay in the prompt application of computers must be the inability of the electronics specialists and the industrial control experts to comprehend each other's problems. Perhaps the chemical engineer may eventually help to bring about a practical fusion of interests.

TODAY

and for

TOMORROW

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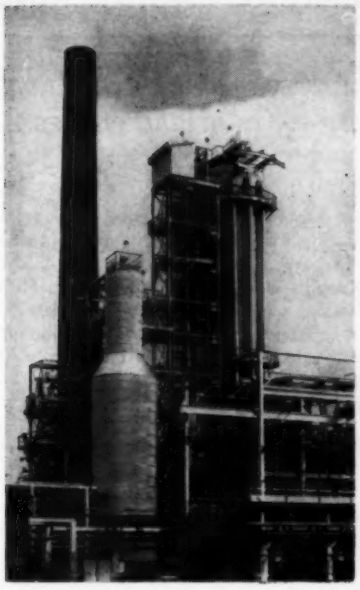

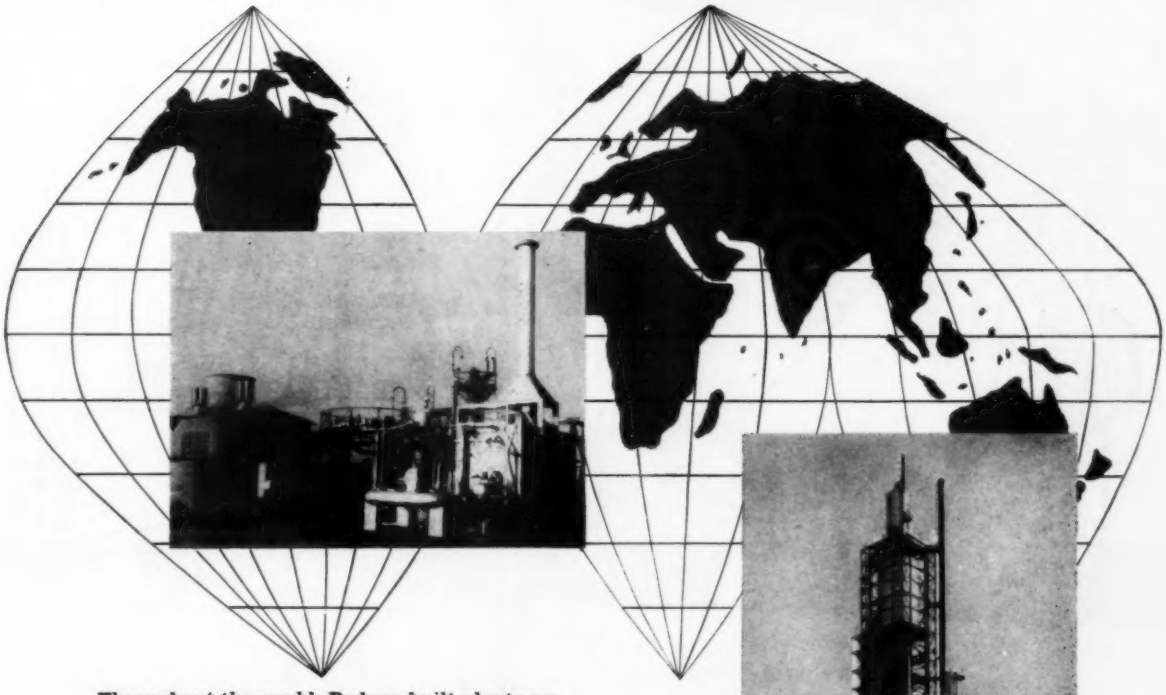

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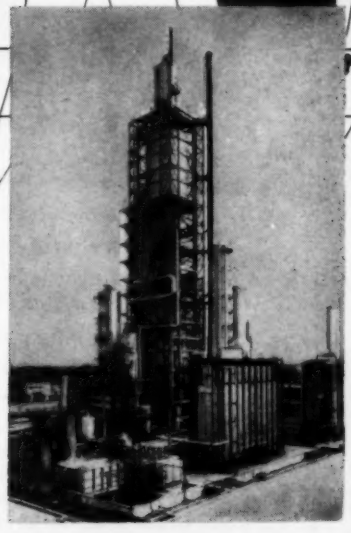

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NOMOGRAM FOR THE CALCULATION OF MINIMUM REFLUX AND FOR THE NUMBER OF THEORETICAL PLATES IN THE SEPARATION OF BINARY MIXTURES

By N. FILIPESCU

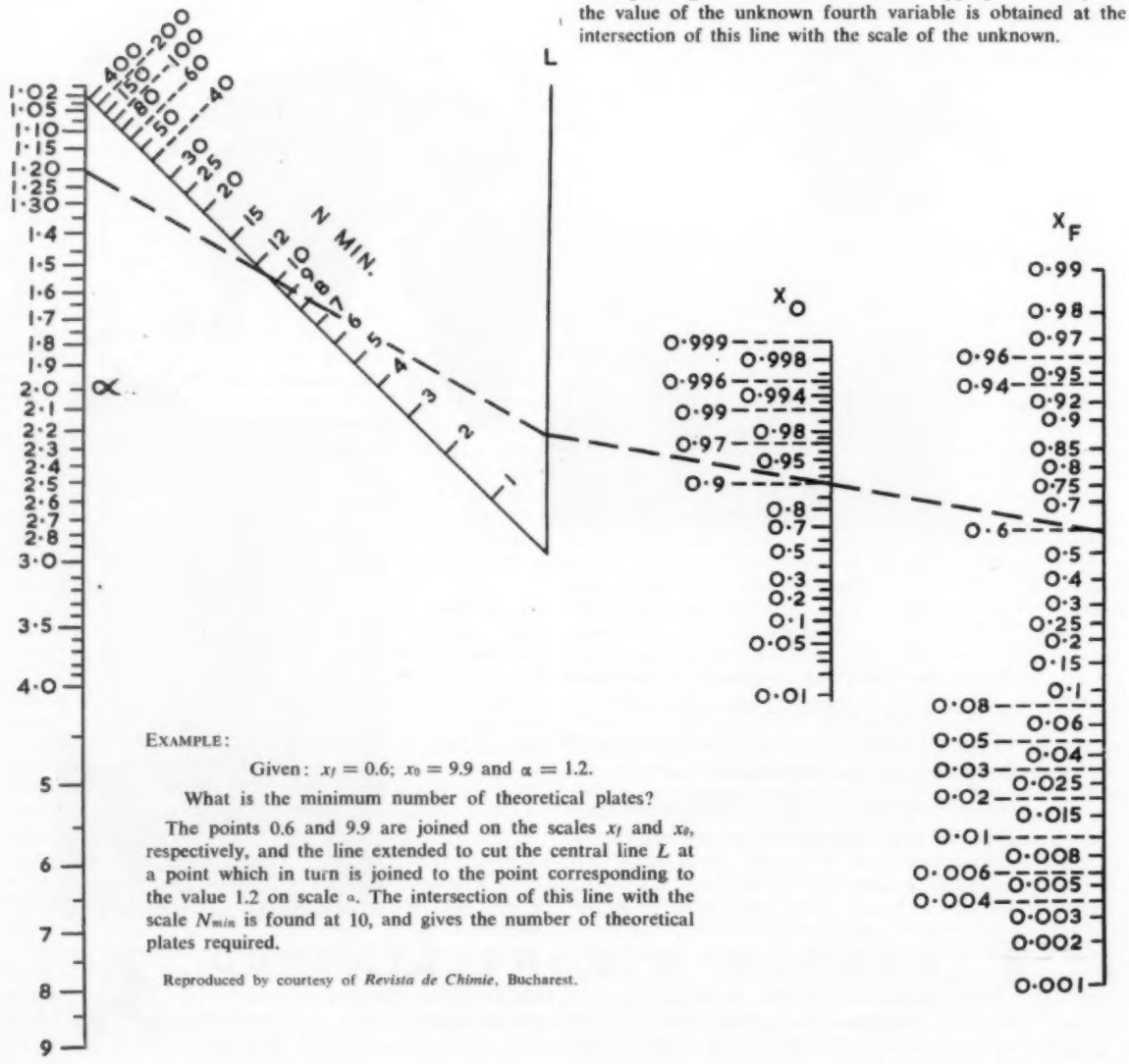
Distillation problems may frequently be simplified in the case of problems of separation to a certain purity involving only two components which have a constant relative volatility and which conform to Raoult's law. Usually one first establishes the limiting conditions; the minimum number of plates for maximum reflux are determined (1), and then the minimum reflux for an infinite number of plates (2). Algebraically, this is expressed as follows:

$$N_{min} = \frac{\log \frac{x_0(1-x_f)}{x_f(1-x_0)}}{\log \alpha} \qquad \ldots.(1)$$

$$\frac{R_{min}}{1+R_{min}} = \frac{x_0 - \frac{\alpha x_f}{1+(\alpha-1)x_f}}{x_0 - x_f} \qquad \ldots.(2)$$

where N_{min} = minimum number of theoretical plates corresponding to maximum reflux;
R_{min} = minimum reflux corresponding to an infinite number of theoretical plates;
x_f = the molar fraction of the more volatile component in the initial mixture;
x_0 = the molar fraction of the more volatile component in the distillate; and
α = relative volatility of the two components.

The nomogram has the four variables represented on four scales: two to the left (N_{min} and α) and two to the right (x_0 and x_f) of the central line (L). Usually two values are known on one side of the line and one value on the other. The two values on the right (or on the left) of the central line are joined and the straight line is extended until it intersects the central line. The point of intersection is joined to the point corresponding to the third value on the appropriate scale, and the value of the unknown fourth variable is obtained at the intersection of this line with the scale of the unknown.



EXAMPLE:

Given: $x_f = 0.6$; $x_0 = 9.9$ and $\alpha = 1.2$.

What is the minimum number of theoretical plates?

The points 0.6 and 9.9 are joined on the scales x_f and x_0, respectively, and the line extended to cut the central line L at a point which in turn is joined to the point corresponding to the value 1.2 on scale α. The intersection of this line with the scale N_{min} is found at 10, and gives the number of theoretical plates required.

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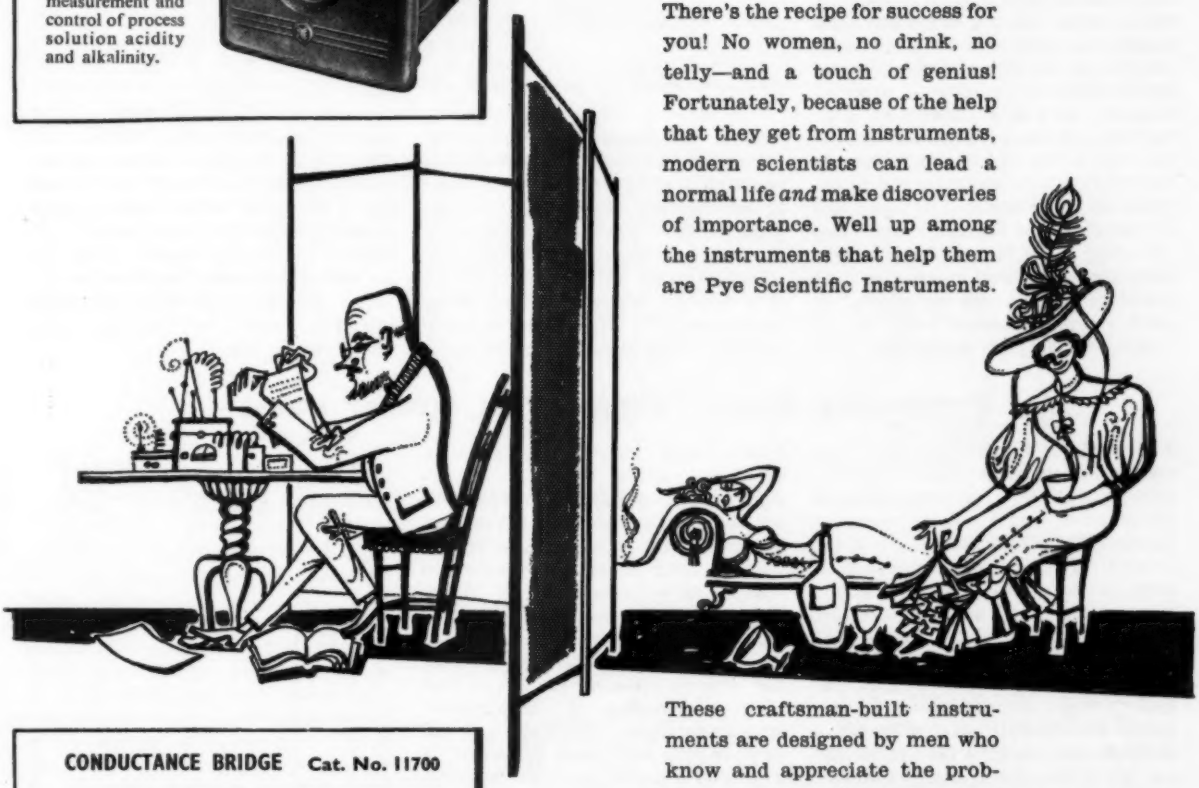

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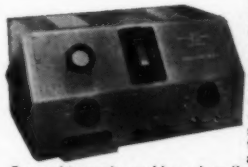

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Novel Laboratory Air Compressor

THE APPARATUS described was devised to meet a temporary but urgent need for a small supply of air at a pressure of about 12 in. of water above atmospheric in a laboratory where there was no compressed air supply. As there was no small compressor or blower available, it was decided to use a laboratory water-jet vacuum pump as a compressor, connecting it up so as to draw in air from the atmosphere and discharge the air-water mixture issuing from the throat outlet into a reservoir. The water and air separated on discharge, the water collecting in the base of the reservoir. Since the water could escape from this container only through an inverted U (with a syphon-breaker vent), the air trapped therein was compressed to a pressure equivalent to the difference in level between the vent or the inverted U-seal and the level of water in the reservoir. Thus air at a pressure greater than atmospheric could be drawn off continuously from the top of the container at a rate equal to that at which the incoming air was being compressed. The arrangement is shown in Fig. 1. The container *or* reservoir used in practice was a three-litre aspirator and the water outlet and inverted U-seal was made flexible so that it was possible to impose various heads upon the discharging water and hence vary the pressure to which the air was compressed. Some results obtained using a standard Edwards laboratory water jet vacuum pump are shown in Fig. 2.

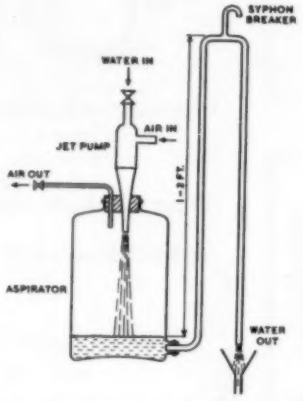


Fig. 1. "Hook-up" of vacuum jet pump compressor.

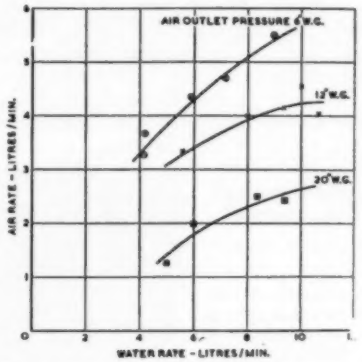
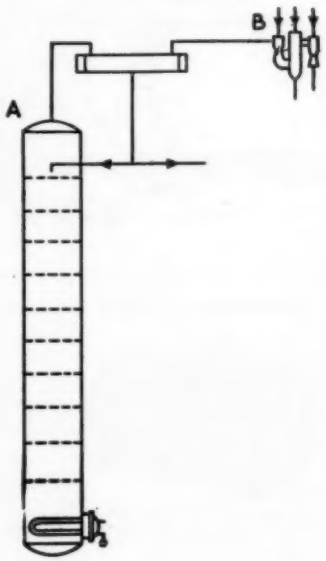


Fig. 2. Performance of laboratory jet pump as air compressor.

Preventing Steam "Slipping" at Ejector Pumps

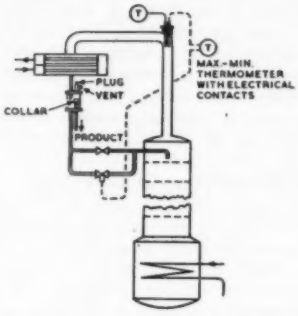
FLUCTUATING STEAM pressures and/or wet steam can lead to troublesome operation of vacuum processes which have ejectors as a source of vacuum. This is particularly so if the volume of evacuated equipment is large. If the working pressure of the steam at the ejector set is too near the "critical" pressure of the ejector (i.e., the pressure which gives the highest vacuum) the operation is unstable because a slight drop of steam pressure below the critical value produces a sharp drop of vacuum. As a result, the vacuum at the plant is higher than that at the ejector and steam is sucked into the process. Referring to the accompanying diagram, in such circumstances the vacuum in part A would be greater than that at B and steam would enter the condenser and the condensed water would find its way into the materials being handled in the distillation column. If a dehydrated product is required the occurrence is a nuisance, but if the product is expensive and at the same time is decomposed by water it can lead to serious losses. Attempts to reduce the effects of steam "slipping" (as this phenomenon is called) by means of non-return valves for isolating the plant when the vacuum falls, or by interceptor vessels fitted with cooling coils, are likely to have only limited success. The best remedy is to make certain that the steam nozzles are designed to operate at a pressure 4 to 10 psi higher than the critical pressure. If the steam supply pressure is close to the critical value for the ejector, then the nozzles should be bored out slightly according to the makers' recommendations. The ejector will then operate with some "choking", a condition essential to stable working. At the same time the steam supply pressure should be controlled. However, if there is a likelihood of frequent interruptions of steam supply, an ejector set is not the proper choice of vacuum source.

Another cause of slipping arises with multi-stage sets when the steam supply is wet. In such cases the trouble frequently originates from the final stage, for here the size of the water droplets and the bore of the nozzle may be of the same order of magnitude. Not only must the pressure of steam be properly maintained with multi-stage sets, but it must also be dried. One way to ensure stable operation is to use compressed air at the final nozzle instead of steam. This may be justifiable when expensive materials are being processed in the plant.



Max.-Min. Thermometer Provides Reflux Control

THE ESSENTIAL components of this system, which is suitable for binary distillations in small batch columns (500 gallons), are a mercury-in-steel dial thermometer fitted with maximum and minimum electric contacts which control the action of a magnetic valve. This valve is placed in the reflux line connecting the glass-walled condensate collector to the distributor at the top of the column. The "minimum" contact causes the valve to close and the maximum contact causes it to open. When the still is working and when the contacts have been correctly set, the magnetic valve will remain closed until the vapour temperature rises through the presence of the less volatile component. At this stage the valve will close and the condensate, instead of being withdrawn from the column, will be returned to it. The column will then operate under total reflux until the purity of the vapour feed to the condensate is restored. The temperature indicated by the thermometer will then fall, the valve will close and the distillate will be withdrawn once more. In order to provide a measure of reflux under these conditions, a by-

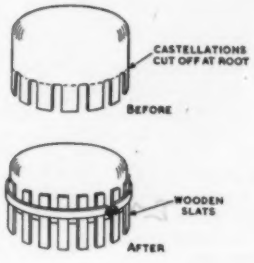


pass is provided at the magnetic valve. This contains a manually adjustable valve which, once correctly set, need not be adjusted for a particular binary mixture.

If it is desired to handle multi-component mixtures once the most volatile component has been withdrawn, the temperature setting of the thermometer can be increased to allow withdrawal of the component next in volatility. An additional thermometer is provided with its bulb installed close to the bulb of the control instrument. This is useful for checking the action of the latter.

Modified Bubble Cap

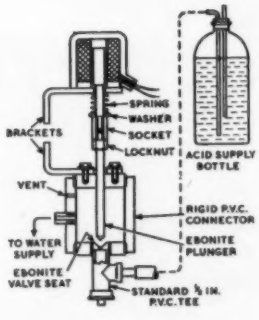
A BUBBLE-CAP absorber which employed a single cap per tray proved troublesome through its inability to permit a steady throughput of gas. The cause of the "gulping" action of the tower was excessive resistance at the bubble caps, due to insufficient slot area. A properly-dimensioned bubble cap was therefore required, but there were objections to one based solely on theoretical calculations. A simple and flexible solution was effected by cutting off the castellated section of the cap and forming the slots by means of wooden strips clamped round the body of the old cap. By adding or removing wooden strips, it was possible to obtain a wide range of slot areas; at the same time, raising or lowering the strips allowed some variation in submergence. After a few trials a combination was achieved which allowed a steady flow of gas through the absorber.



Feeder for Control Of pH Cooling Tower Water

THIS IMPROVISED feeder constructed from a discarded magnetic valve and standard rigid P.V.C. pipe fittings proved a cheap and reliable means of adjusting the *p*H of cooling-tower water. In essence, the device is a home-made magnetic valve connected to a supply of dilute acid which is fed in small quantities to the mass of water in circulation, during the periods when make-up water is being supplied to the cooling system. This can be brought about through a timer connected to the make-up water meter if one is installed, by a micro-switch operated by the make-up valve, or by a float switch operating off the water level at the hot well.

The P.V.C. socket-cum-valve body, which is 1½ in. to 2 in. nominal bore, is closed by two plugs, the upper one drilled to allow the ebonite plunger to pass through and the lower a standard fitting to take the valve seating and the T connection. The joints should be made with suitable jointing



paste. The size of the orifice is important, since the amount of acid delivered is dependent upon the rate of flow and the time during which the plunger is off its seating. A measure of control of the acid flow is afforded also by the Mariotte tube which can be raised or lowered to vary the head of liquid over the valve seating.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Chinese Chemical Developments

Work has started on a chemical plant at Taiyuan, in North China, for the production of sulphuric and hydrochloric acids, caustic soda, liquid chloride, phenol indigo, 666, D.D.T. In the same district the construction of a chemical fertiliser plant and of a pharmaceutical plant manufacturing sulphonamide drugs and vitamins will be commenced this spring. All of the factories are being designed and built with Soviet assistance. In Dairen work has begun on the expansion of the chemical fertiliser plant in an attempt to treble its annual output to 800,000 tons. The joint state-private Ungli Chemical Works in Nanking is being extended to yield an additional 80,000 tons of ammonium sulphate annually, and a new ammonium sulphate plant is to be added, equipped with Czechoslovak machinery.

For the district of Kwangtung a concentration of sugar plants is planned. On Hainan Island three refineries with a daily pressing capacity of 350 tons will be built and a refinery (420 tons) transferred to it from elsewhere. In Chanchiang five refineries (350 tons) will be erected and a refinery (300 tons) transferred from elsewhere. In Hopu one refinery (350 tons) will be built and another (250 tons) transferred from elsewhere. A new sugar mill in Auch'ing, Anhui province, is to produce 90,000 catties (just over 30 tons) of brown sugar a day, on a production schedule of 120-150 days a year.

The Kiamusze paper mill, one of the 156 major projects built with Soviet assistance, has begun production of paper for industrial uses.

Investment in Indian Chemical Plant

New chemical plants are being erected by I.C.I. in India for three separate companies in which I.C.I. is in partnership or in association with Indian capital. When completed in a year or 15 months' time, these will add £9 million to the total investment in the Indian chemical industry in the private sector—in Atic Ltd., at Bulsar (Bombay State), in the Alkali & Chemical Corporation of India Ltd., at Rishra (West Bengal), and in Indian Explosives Ltd., which is a joint partnership concern of I.C.I. Further schemes at present under discussion may raise the investment total to £12 million.

Mexican Fertiliser Plans

The Mexican Nacional Financiera, Guanos y Fertilisantes S.A., and the finance house Sociedad Mexicana de Creditor Industrial S.A. are joining forces to build an anhydrous ammonia plant at Salamanca with a capacity of 100 tons a day. Total investment in this plant, to be called Fertilisantes del Bajio S.A., will be 83 million pesos (£2.38 million). In addition, Guanos is to build a plant at Coatzacoalcos, to produce 150 tons of triple superphosphate and 100 tons of simple superphosphate daily; a plant at Tampico, to produce 150 tons of superphosphates and sulphuric acid daily; and extensions to the Cuatitlan ammonium-sulphate plant, to increase its capacity to 150,000 tons yearly. Fertilisantes de Monclova is expected to come into production during the last quarter of 1958.

Starch Processing Organisation

W. A. Scholten's Chemische Fabrieken NV at Foxhol, Holland, has acquired a large interest in Morning Star, Nicol Inc., New York, in exchange for its assets in the starch-processing company, Haberland Manufacturing Co. The Haberland factories will be enlarged and plans are in hand to market a number of newly-developed products, probably including a new cheap soil stabilising agent for use in wind-eroded areas.

Canadian Detergent Alkylate

Imperial Oil's new dodecyl benzene plant at Sarnia, which has a designed capacity of 30 million lb. annually, was commissioned recently. It is the first installation to manufacture this product in Canada and it was completed at the cost of about $5 million. By-products include tripropylene and heavy alkylate. With the opening of the plant, Imperial Oil have entered the petrochemical field.

Plastics Materials Record

In 1957, exports of plastics raw materials from the United Kingdom, more than 11,800 tons valued at £29.2 million, set a new record. The tonnage represents an increase of more than 50% in three years. Australia was again the biggest buyer, with imports valued at over £4 million, against £2¾ million in the previous year.

High-energy Fuel

The new plant for the manufacture of sodium borohydride at the installation of Metal Hydrides Inc., Danvers, Mass., is working an "essentially continuous" process and includes a unit for the continuous production of methylborate from boric acid and methanol. The product is being transferred to plant of Olin Mathieson at Model City, New York, for conversion into high-energy fuel.

Greek Sugar Factory

The establishment of a sugar factory in the Larissa or Salonica district capable of processing 2,000 tons of sugar beet daily is planned by the Greek Government. It is expected that construction work will commence in the middle of this year.

New Components-handling Building

A new building has just been completed at the Atomic Energy Research Establishment, Harwell, in which components of future power reactors, such as fuel, can and moderator materials, which have been subjected to intense radiation in testing circuits in the DIDO and PLUTO reactors, will be prepared for examination and testing. The building is designed to handle radioactive materials at levels up to 100,000 curies.

Indian Salt Industry

The Government of India has set up a committee to inquire into the working of the salt industry and to recommend measures for its development.

I.C.I. Isocyanates Production

A new organic-isocyanate plant has been brought into production at the Huddersfield factory of I.C.I. Dyestuffs Division. The products are to be supplied as curing agents for use in conjunction with polymeric reactants.

German Titanium-dioxide

A £8.5-million titanium-dioxide plant for Bayers was commissioned recently at Urdingen, near Krefeld. It has an initial output of 15,000 tons a year, and this is to be raised soon to 50,000 tons.

Ammonia Plants for Sicily

Two new Casale synthetic ammonia plants are now under construction in Sicily. They will have a daily capacity of, respectively, 130 and 65 tons of nitrogen.

Dutch Nitrogenous Fertiliser Plant

A new nitrogenous fertiliser plant having a capacity of 125,000 metric tons of fertiliser, or 25,000 metric tons of pure nitrogen, annually, has been commissioned by Mekog N.V. at Ijmuiden. The process uses fuel oil as a raw material.

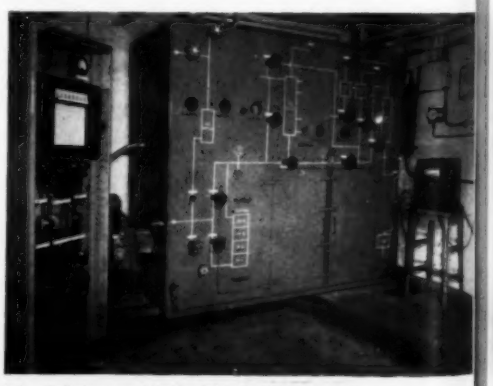
New Products

Thiobenzoic acid, a bright yellow volatile liquid—Robinson Bros. Ltd., West Bromwich.

α-2-carbomethoxy-1-methyl vinyl dimethyl phosphate, a systemic insecticide —Shell Chemical Co. Ltd.

A range of technical and pure metallic borides and boron phosphate—Borax Consolidated Ltd.

Sucrose esters, non-ionic surface-active agents—Howards of Ilford.



The rig being used in the Chemical Engineering Division, A.E.R.E., Harwell to study ion-exchange behaviour of materials such as zirconium phosphate at about 300°C. The assembly within the cabinet operates at pressures up to 2000 psig

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Book Reviews

Behaviour of Metals at Elevated Temperatures
liffe, London, 1957, 122 pp., 21s.

THE design of chemical plant, power units and airframe structures to withstand high temperatures and high stresses is becoming increasingly difficult and assuming great importance. When one considers high-temperature and pressure reactions in chemical synthesis, gas turbines and jet engines, and high-pressure steam plant with high superheat and aeroplane and rocket speeds of relatively high Mach numbers, it is no exaggeration to say that a knowledge and understanding of properties of materials at high temperatures are vital to the future of engineering practice and design.

The Institution of Metallurgists has performed a public service in producing this book which serves to focus attention on a very important branch of metallurgy. In 1956 their annual refresher course was devoted to a study of the behaviour of metals at high temperatures and the four lectures then delivered are reproduced here in book form.

The topics are well chosen and the first paper by DR. N. P. ALLEN, F.R.S., of the N.P.L., deals in a general way with the fundamental properties to be considered, viz.: stability of physical properties and dimensions; elastic constants and coefficients of expansion; resistance to plastic deformation and fracture under constant stress and the effect of complex stresses; behaviour under fluctuating stresses; behaviour under fluctuating temperature; resistance to chemical attack, with or without simultaneously applied stress. Few would quarrel with this selection, though some would doubtless wish to have welding included. Quite legitimately, considerable attention is paid to creep and a very fair picture of the present state of knowledge of this aspect is given. The paper concludes with a section suggesting methods of developing new alloys for use at high temperatures.

After this introductory paper, G. MEIKLE, of the Royal Aircraft Establishment, Farnborough, deals with the effect of temperatures up to 450°C. As one would expect, this paper is written almost exclusively for the aircraft designer and hence some very interesting results with aluminium alloys of the precipitation-hardening type are presented and compared with those obtained with titanium alloys, nickel-cobalt alloys and special steels when used for the particularly arduous conditions obtaining in various parts of an airframe structure.

This paper is followed by DR. L. B. PFEIL'S contribution from the Mond Nickel Laboratories on non-ferrous high-temperature alloys—interpreted as those with not more than 50% iron content. A wide range of metals and alloys is covered, including the platinum metals, spray-coated molybdenum alloys and those alloys where nickel is the chief constituent. Attention is drawn to the importance of cold work plus precipitation hardening to achieve high strength at moderately high temperatures. All through the paper creep properties and rupture stress are kept in mind.

The final paper on high-temperature steels is written by W. E. BARDGETT of United Steels and covers in masterly fashion steels of all kinds likely to be used at elevated temperatures. Here again emphasis is laid on creep and stress rupture properties, while the effect of alloying constituents on carbide formation is very fully dealt with. Other topics include high-temperature ductility and the ability to accommodate internal stresses due to repeated heating and cooling cycles and notch sensitivity.

If the chemical engineer expects to find in this book the answers to all his high-temperature design problems neatly served on a plate he will be disappointed. Nevertheless, if he has some knowledge of metallurgy he cannot fail to find here much new and useful information; he will certainly be able to learn what sort of service to expect from a wide variety of metals. The four papers make stimulating reading and the selection of references supports or augments the subject-matter. Chemical engineers may wish that a fifth paper had been included dealing specifically with the problems met in chemical plant design for high-temperature work where corrosion is also present (or likely to occur), but from the point of view of the Institution of Metallurgists it must be conceded that the four authors have covered a very wide field in a most able manner.

H. W. THORP

Human Engineering
by E. J. McCormick
McGraw-Hill, London, 1957, 467 pp., 62s.

THIS is the most comprehensive book on human engineering which has yet been published. It discusses in some detail the best designs and layouts of instruments and controls for men to use, space requirements, and the optimal arrangement of equipment. It also contains chapters on the effects of lighting, noise, atmospheric conditions and acceleration forces on machine operators.

The author outlines the underlying scientific facts, and describes representative laboratory experiments and their results, in addition to giving his recommendations. He also mentions practical instances of improvements made by the application of human-engineering principles. There are numerous tables, graphs and illustrations. At the end of each chapter he gives a clear summary, and some useful selected references. He concludes on pages 439-41 with 18 Principles of Human Engineering, which everyone who designs equipment for men to use should always keep in mind.

In the chemical industry the book is to be recommended particularly to instrument engineers and to those engaged in work (method) study. In the design of large-scale plant, most of the starting-up switches and instruments, whether recorders, controllers or combined controllers and recorders, can now be concentrated in control rooms. A control room can be designed and instrumented in numerous different ways. There are thus great opportunities for selecting instruments and switches, and for laying them out, to make the task as easy as possible for the process man so that he can start up the plant and keep it running with maximum efficiency. The details of these optimal designs have in many cases still to be worked out. In the meantime, designers ought not to follow uncritically conventions handed down from an age when less consideration needed to be given to the capabilities of process men.

E. C. POULTON

Men, Steel and Technical Change
H.M.S.O., London, 1957, 2s.

HOW DOES TECHNICAL change, notably that which leads to automation, affect employees and their relations with employers? What makes them view it with favour—or disfavour? In what conditions do they accept it rather than resist it? There have been several recent studies of these questions usually confined to particular aspects like changes in skills and status. This booklet, by contrast, springs from an intensive survey of the problems in one company making steel. It traces the relationship between technical and social changes especially during the last twenty years. It forms the first of a series of short books issued for industry by the Department of Scientific and Industrial Research. The survey was carried out by a section of the Department of Social Science in Liverpool University. It covers technical changes, problems of management and their relations with trade unions and finally the attitudes of employees to change.

On the Old Lines
by Peter C. Allen
Cleaver Hume Press Ltd., London, 188 pp., 25s.

PETER C. ALLEN, former chairman of I.C.I. Plastics Division, has published a book on his hobby-subject, the steam locomotive. "On the Old Lines", as the new book is entitled, is to a great extent a picture-book, with photographs on every right-hand page and informal talk and reminiscence on every left. The European section is especially rich on Spain, where many endearingly antiquated machines still survive. The pages are illumined with curious pieces of information, such as that a locomotive in Western Australia needs as much water as 17,000 sheep, and why Peruvian peasants wear trilby hats.

1958 Buyers' Guide. Supplement to "Chemistry and Industry", December 7
Society of Chemical Industry, London, 1957, 5s.

THE 1958 Buyers' Guide again covers chemicals, chemical plant and laboratory equipment separately—each alphabetically indexed, with a list of suppliers under each item. This is a very useful reference work which would probably benefit by the introduction of thumb tabs to enable selection of desired sections.

A Treatise on the Internal Mechanics of Ball, Tube and Rod Mills

by H. E. ROSE and R. M. E. SULLIVAN

Ex. Cr. 8vo. Illustrated about 21s.

Chemical Engineering Operations

An introduction to the Study of Chemical Plant

by F. RUMFORD, Ph.D., B.Sc., M.I.Chem.E.

Demy 8vo. 376 pages Illustrated 32s. 6d.

Chemical Engineering Materials

by F. RUMFORD, Ph.D., B.Sc., M.I.Chem.E.

Demy 8vo. 350 pages 32s. 6d.

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Milton J. Allen

Director of the Physical Research Laboratories CIBA Pharmaceutical Products Inc., Summit, N.J.

Electro-Chemistry, a bulwark of the inorganic chemists, has not yet been fully adopted by organic chemists, and Mr. Allen has written his book with this in mind. He has devoted his whole career to organic electro-chemical investigations involving methods of preparation of organic compounds utilising oxidation or reduction techniques. His studies have also encompassed the mechanisms and kinetics of organic electrode processes. The book should give organic chemists the fundamental information to start investigatory work.

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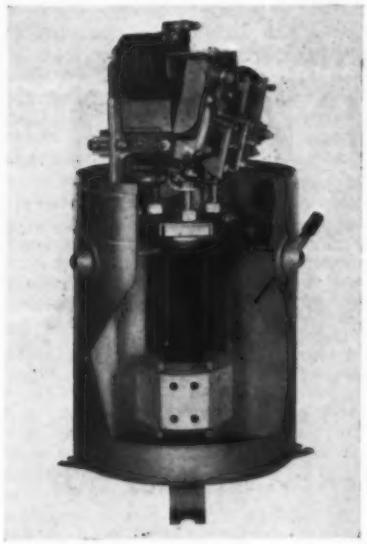


Novel Starter

A novel automatic starter for slip-ring motors is being made available in the United Kingdom and most of the Commonwealth by Lee Guinness Ltd. under licence from the French company, A.O.I.P. Suitable for normal load duties including those of compressors, pumps and ventilation equipment, it compares in price, the makers point out, with hand starters (which the company also make). The principle on which the Vapormatic rheostat, as the equipment is called, is based on the large difference in resistance of a liquid electrolyte and its vapour (about 1 : 50). Essentially, the apparatus consists of two electrodes located opposite each other in a small chamber of insulating material. The chamber is submerged in a tank of electrolyte with which it communicates by small orifices that offer a known resistance to the flow of liquid. When a high current is passed through the electrodes across the chamber the electrolyte resistance causes local heating and almost instantaneous vaporisation of the electrolyte between the electrodes. The chamber is therefore quickly filled with vapour and the resistance in the circuit is at its maximum. The resistance introduced into the circuit varies proportionately to the amount of energy. Advantages claimed for the equipment include smooth acceleration, automatic regulation of the rota current and considerable saving of space. The starters are made in units of 40-hp capacity and they may be connected in parallel for motors of greater rate. Tests conducted at the A.S.T.A. testing station of Crompton Parkinson Ltd. confirm that the resistance induced in the circuit by the Vapormatic reaches its maximum value almost instantaneously and is progressively eliminated in contrast to the steps of conventional starters. Other possible applications for the apparatus are being investigated, included the handling of heating loads and the starting of squirrel-cage motors. The electrolyte is a 20% solution of either potassium carbonate or sodium carbonate. **Lee Guinness Ltd., Newtownards, Northern Ireland.**

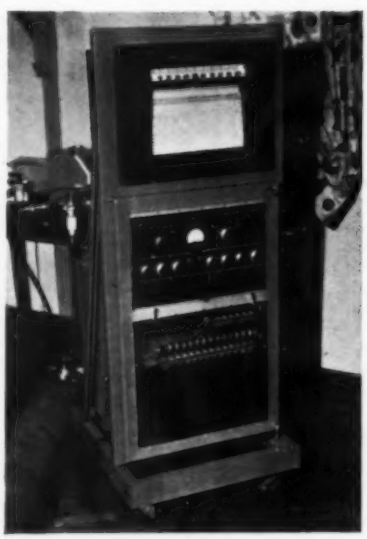
BCE 2754 for further information

New Process Instruments

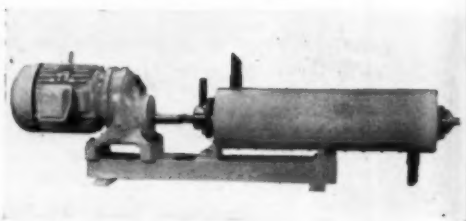
Four industrial instruments new to Britain—a gas-chromatograph for the monitoring of process streams, an electrolytic hygrometer, a leak detector, and an infra-red gas-analyser produced by Beckman Instruments G.m.b.H., Germany—are being supplied by Winston Electronics, the sole selling agents in the United Kingdom. The industrial gas chromatograph, model 220, is designed specifically for the continuous monitoring of industrial gas systems. Sample gas is continuously bled from a main process stream and led through the instrument's linear sample valve which is said to be of unique design. Periodically, up to once every five minutes, the valve transfers the contents of the sample loop to a constant stream of carrier gas. The sample is flushed through a chromatograph column, containing absorptive or adsorptive granules. Each component registers its passage through a thermistor sensing cell by changing the thermal conductivity of the carrier gas. A second thermistor cell, measuring pure carrier gas, serves as the second leg of a Wheatstone bridge circuit. Signals from this are transmitted to a strip chart recorder, where they are presented either as a spectrum of the entire mixture or as a bar graph of important components.

The electrolytic hygrometer is an instrument for the continuous or batch measurement of water content down to one part per million in gaseous or vapour samples. It continuously absorbs and electrolyses any water present in a sample stream that enters the instrument's analysing system. Streams of temperatures of up to 100°C can be examined by it. The leak detector is a radio-frequency mass spectrometer which will detect and measure leaks of, it is said, almost any size at any pressure range in vacuum and pressure systems and in hermetically-sealed units. The infra-red analyser examines a mixture of gases for only one component. It contains two sources of infra-red light which is chopped at 10 cycles a second. Part of the light is absorbed in the flow cell for the sample, and the reference cell. Normally, the filters or windows of the cells are tuned to the requirements of the special application, and more light is absorbed in the flow cell than in the reference cell. The remaining beams go into a detection cell, and the temperature in the cell is increased. This is transformed into a pressure on a microphone detector and the result is measured at intervals of a second. **Winston Electronics Ltd., Shepperton, Middx.**

BCE 2755 for further information



Rotary Heat Exchanger



The latest Rota-Pro continuous rotary scraped-surface heat exchanger is the junior model designed for pilot plant and experiment work. It is a single-cylinder machine based on the design of the full-scale models which recently were made generally available. The machines are designed for heat exchange of viscous liquids, and liquids containing a high proportion of undissolved solids above their normal boiling points or below 0°C. The processing cylinders are fabricated from non-corrosive metal, are faced with hard chrome internally, and are honed to a mirror surface. Inside each cylinder a mutator shaft fitted with two scraper blades of hardened stainless steel is caused to rotate, the speed of revolution normally being fixed at a chosen value. The cylinder is surrounded by a jacket for the heating or cooling medium, and the jacket is insulated and sheathed with stainless steel. To maintain a high efficiency of heat transfer, the scraper blades are in intimate contact with the inner surface of the cylinder to continually scrape it clean. The jackets can be heated with high-pressure steam or

We designed the micromerograph to solve our own particle problem...

. . . but it was too good to keep to ourselves

When you're dealing with separation problems every day it's essential to be able to measure accurately the size of very small particles.

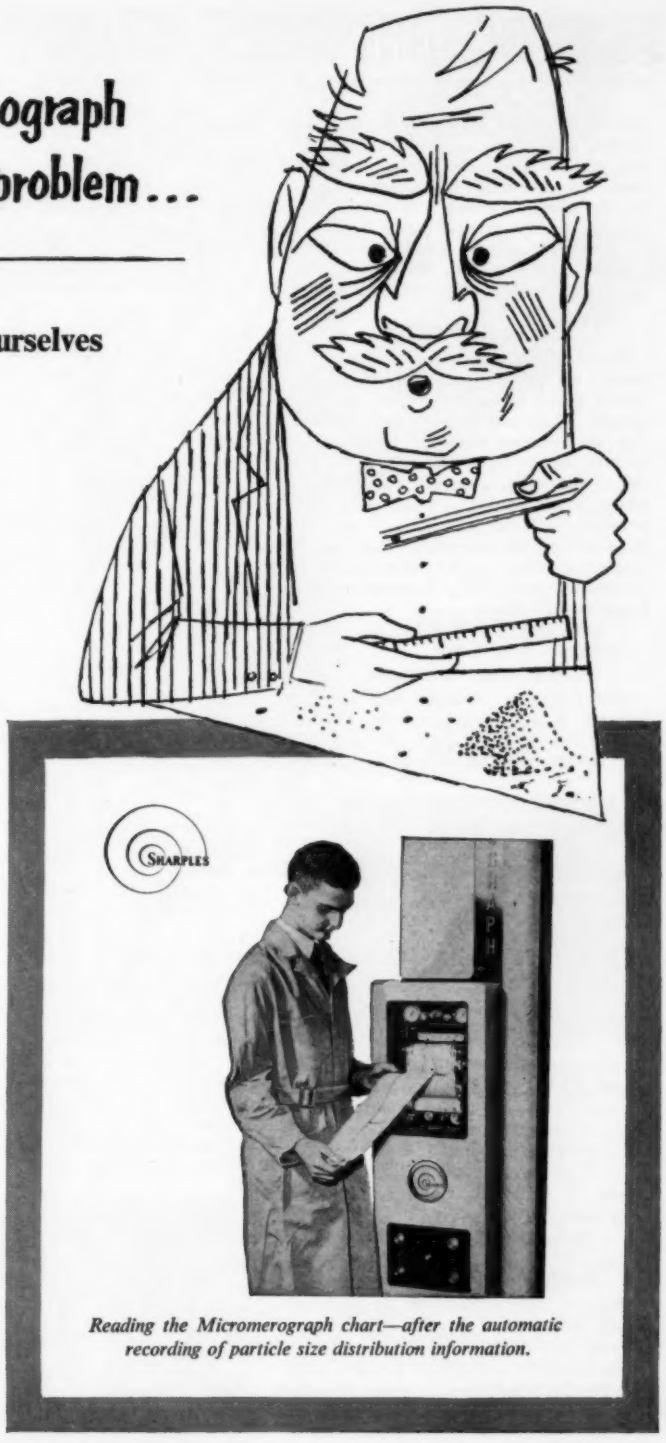
All the existing methods had their snags. So we set about developing our own instrument. And over the years we developed the Micromerograph. It was so highly successful that we felt we ought to manufacture it and offer it to others who need a rapid, accurate, reproducible means of particle size analysis. It is now in use in a wide variety of industries.

The Micromerograph uses the air sedimentation technique which can be operated with solids in low concentration, due to the simultaneous development of a high precision null-deflection balance. The built-in deagglomerator applies a controlled and reproducible shear force to the powder sample so that particle aggregates can be broken down, whilst causing no destruction of individual particles. An automatic recorder gives a continuous statement of data.

The whole instrument is robust and automatically operated. Relatively unskilled personnel can use it. The Micromerograph has put into the hands of industry a means of production control and research which was previously unobtainable. Already many users have obtained dramatic improvements of product quality due to their use of the Micromerograph.

Another example of particle handling by Sharples is the new Sharples Super Classifier—a unique air vortex classifier that combines an ultra-sharp cutpoint with high capacity and unmatched efficiency. Write for Bulletin 1280 describing the Super Classifier.

Write for Bulletin No. 456M describing the Sharples Micromerograph or, if you wish, phone Camberley 2601 and talk to Martin Trowbridge about your problem.



Reading the Micromerograph chart—after the automatic recording of particle size distribution information.

SHARPLES

Sharples manufacture a complete range of Continuous Centrifuges, including—

THE SUPER-CENTRIFUGE SERIES · THE DD-2 DISC BOWL SERIES · THE DH-2 NOZLJECTOR SERIES · THE DG-2 AUTOJECTOR SERIES · THE DV-2 VALVE NOZZLE CENTRIFUGE SERIES · THE SUPER-D-HYDRATOR CRYSTAL CENTRIFUGE SERIES · THE Q-18 SELF-DISCHARGING CRYSTAL DEWATERER SERIES · THE SUPER-D-CANTER SLUDGE DISCHARGE CENTRIFUGE SERIES · THE 1A LABORATORY CENTRIFUGE SERIES · THE SUPER CLASSIFIER SERIES · THE SHARPLES MICROMEROGRAPH.

SHARPLES CENTRIFUGES LTD., TOWER WORKS, DOMAN ROAD, CAMBERLEY, SURREY. *Telephone: Camberley 2601*

PLANT EQUIPMENT NEWS

cooled by liquids or by direct-expansion cooling with ammonia. Up to three tubes can be mounted on a single common base for identical or different heat-transfer media, so that both heating and cooling can be carried out if necessary in a single machine. **Clarke-Built Ltd., Power Road, London, W.4.**

BCE 2756 for further information

Computing Relays

Foxboro-Yoxall have introduced a range of seven Consotrol computing relays, based upon their M/58 controller design. They are of the force-balance type and operate normally in the range of 3-15 psi for input and output signals. Six of the relays undertake, respectively, adding, subtracting, multiplying and dividing, and the seventh is a general-purpose or universal relay which can be made to perform any of these operations. **Foxboro-Yoxall Ltd., Lombard Road, London, S.W.19.**

BCE 2757 for further information

New Range of Pumps

Plenty have introduced a new range of positive-displacement variable-delivery pumps known as types 200, 500 and 1100 and suitable for oil-burning equipment.

They are fitted with delivery and pressure regulating valves which enable the pumping units to be set for optimum circulating and heating conditions. The maximum working pressures and temperatures are, respectively, 200 psi and 250°F. **Plenty & Son Ltd., Eagle Iron Works, Newbury, Berks.**

BCE 2758 for further information

Solids Flow-failure Detector

Baileys have introduced an electronic solids flow-failure device, incorporating transistors, which has been designed to provide visible and audible warning when the free flow of solids in an enclosed pipe or chute ceases. It operates by amplifying the vibration caused by the material in progress, and it causes virtually no obstruction to flow, the makers say. The circuit is printed and the equipment, it is claimed, is unaffected by vibration or by dust- and grit-laden atmospheres. Although the device has been developed to operate with coals, the makers state that it can be applied to other solids which are of the same order of hardness as the coals generally used for steam generation, and experience of operation with a variety of solids is being gained. The instrument consists of an acoustically-isolated probe inserted into the pipe to make contact with the moving solid. **Bailey Meters & Controls Ltd., Purley Way, Croydon.**

BCE 2759 for further information

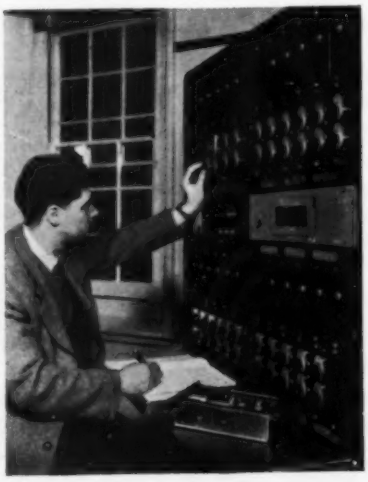
Air-operated Dispensing Pump

Gilbarco are marketing an air-operated pump for the dispensing of liquids of medium and high viscosity including lubricating oils. The pump works on compressed air at pressures between 60 and 120 psi. Air admitted to the cylinder by the control valve sends the piston to the bottom of cylinder (power stroke), and, in the return stroke, air released to the atmosphere by the control valve allows the piston to rise and suck in liquid through the non-return valve. At the commencement of the return stroke, liquid is momentarily sucked back through the discharge tube until the spring-loaded ball valve at the cylinder head is reseated. This slight vacuum action tends to withdraw a small quantity of liquid from the proximity of the discharge nozzle to avoid dripping troubles. **Gilbarco Ltd., 66 Parkway, London, N.W.1.**

BCE 2760 for further information

Computer Units

Solartron Electronic are offering a range of units which can be built in stages into analogue computers and simulators. The range includes drift-corrected D.C.-amplifiers and heater supply and H.T. stabilised power-units. Sub-unit racking, nesting assemblies and special system reference and non-linear computing units are also available to facilitate expansion of existing computer or simulator installations. Applications of the equipment include synthesis of closed-loop and servo controls and simulation of complex flow problems in chemical and other industrial processes. The safety factor of dangerous processes may easily be determined without danger



and the equipment may be used to speed up the actual time scale of operation of any process, so that processes which normally recycle over periods of many hours or days can be examined under dynamically-accurate conditions inside, it is said, a few minutes of computer operating time. **Solartron Electronic Group Ltd., Thames Ditton, Surrey.**

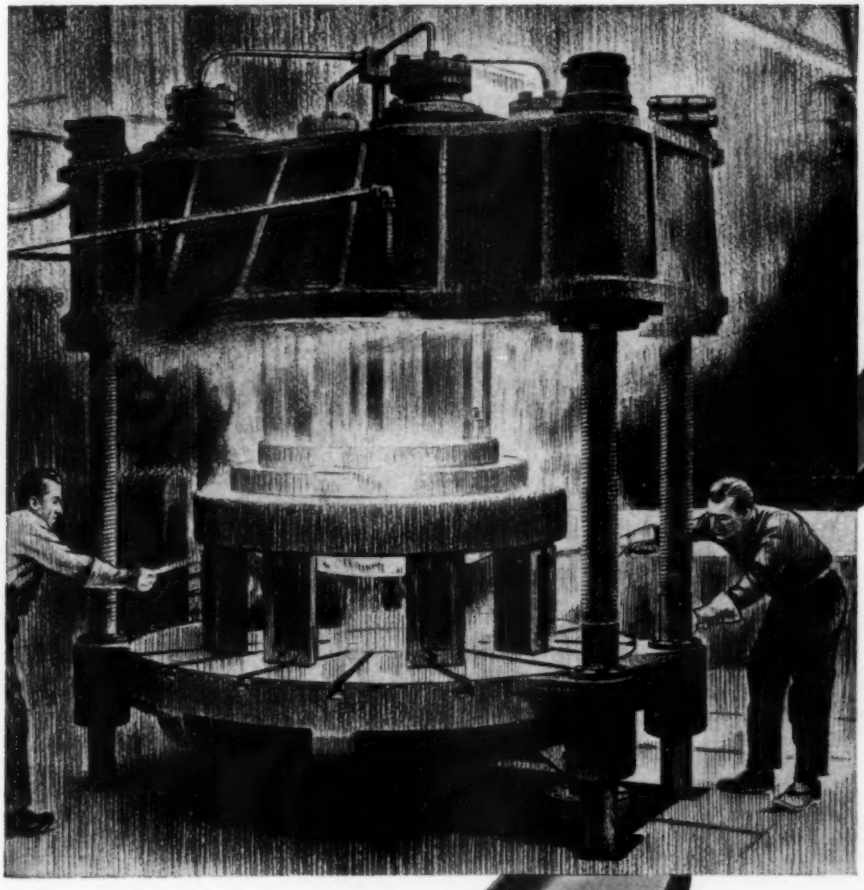
BCE 2761 for further information

Air Filtration Equipment

Two designs of air-filtration and gas-cleaning plant that have been in continuous use in the U.S.A. for 25 years—Far-Air viscous impingement filter and

Rotonamic centrifugal filter equipment—are now being made under licence in Great Britain by Intermit. The impingement filters consist of panels of electroplated zinc wire mesh in alternate layers, flat and crimped in a herringbone pattern, so making channelled triangular openings which face the incoming air flow. This construction, Intermit say, permits air to go through the filter media at high velocity and very turbulently. As the orifices of the mesh on the entering side of the filter become covered with a dirt load, the triangular channels divert the air flow to the clean mesh, it is said, where the filtering function is continued. The recommended net face velocity for normal duty is 519 fpm, which, with a type 44 filter 2 in. thick, is equivalent to a capacity of 3.60 cfm in². The pressure loss is 0.12 in., the company say. With this filter 99% efficiency has been obtained by the makers with dusts of particle size 40-80 microns (using 20 gm. of dust) and 87.7% for particle size of up to 5 microns. The oil with which the meshes are coated quickly gels, and, it is claimed, is not carried in suspension by the air. Automatic self-washing assemblies of the filter which can remain in service continuously are available. For removing the smallest range of particles, an H.P. strainer filter consisting of an accordion-pleated paper filter and wire retainer is available for use in conjunction with impingement equipment.

The Rotonamic uses a high-velocity air stream to separate air-borne solid particles by centrifugal force. The centrifuged particles continuously scour the internal components and this action, it is claimed, eliminates the need for servicing. A standard assembly measuring 20 in. × 20 in. × 4¼ in. contains 64 cyclonic



DISHED and FLANGED ENDS

Fabrication of pressure vessels may be greatly facilitated by drawing upon Harvey resources for the production of die-pressed Dished and Flanged Ends.

Capacities range from 6 in. to 9 ft. diameter. Edges are prepared for welding or riveting if desired.

STOCK SIZES : Ends pressed from Boiler Quality or Ship Quality Mild Steel up to $\frac{1}{4}$ in. thickness, in most sizes up to 7 ft. diameter, are normally available from stock.

SEMI-ELLIPSOIDAL HEADS can be produced on the Rotarpress ; diameters 5 ft. to 15 ft. ; thickness $\frac{3}{8}$ in. to 4 in.

For details, please ask for List No. BCE965.

Harvey

G. A. HARVEY & CO. (LONDON) LTD. WOOLWICH ROAD, LONDON, S.E.7 GREenwich 3232 (22 lines)

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separator units arranged in parallel, and it can handle between 1000 and 2000 cfm of air. The incoming unfiltered air enters each intake tube through deflecting vanes which produce a velocity vortex. The dust particles are centrifuged outwards and are carried by bleed-off air through an annular orifice into the dust discharge hopper. The main air-stream, still whirling, reverses direction and travels towards the inlet around the outside of the discharge tube, so providing a second cyclonic action. Efficiency, it is said, averages 98% on particles of specific gravity 2.5 in the 5- and 15-micron range and is high on larger sizes. **Intermit Ltd., Bradford Street, Birmingham, 5.**

BCE 2762 for further information

Sleeve Air Filter

The patents covering the new Bivac Clear-Flo air filter relate to the filtration of powders that include particles of size 0.5-0.1 micron at a high dust loading. The equipment consists essentially of a number of spring-distended fabric sleeves, the bottom closed-end of each being sealed off and the top open-end secured to a common header box. Air travels from the outside of the sleeve to the inside, and the collected dust remains on the outside of the tube of cloth until variation in fan-pull causes the internal spring to contract. The cloth sleeve then also contracts and cracks off the collected powders. Bulk loadings of dust with an average particle size of one micron have been collected with, so far as the company can measure, 100% retention. The apparatus can operate with temperatures of the feed air as high as 400°C. Bivac have test rigs available for trials on their own and their clients' premises. **Bivac Air Co. Ltd., Stockport.**

BCE 2763 for further information

Drum Mixer

The PEP mixing machine has been designed primarily for mixing paint in 5-gallon drums or smaller containers. It incorporates pairs of eccentric cams mounted angularly on a horizontal shaft and driven by a ½-hp motor to give a combined shaking and rotary movement. The containers are placed directly on the cams, which are adjustable to cater for various drum lengths. **Engineering Tool & Product Design Co. Ltd., 126 Crossbrook Street, Waltham Cross, Herts.**

BCE 2764 for further information

Level Controller

Fieldens have introduced a new level controller, the Tektor Major. Although it is a development from their J model and operates on their patented capacity principle, the instrument has a different circuit and provides an improved performance, Fieldens say. It is more stable, for example, and its sensitivity can be preset to the level of its capacity. The sensitivity is said to be better than 1.0 pF under all conditions. Negligible effects ensue from a ±10% change in supply volts or an ambient temperature change of from −20°C to 50°C. For the high-level model the length of cable can be as much as 35 ft, or for the low level model 20 ft, so that the instrument may be installed some distance away from the probe. Prototypes of the Major have been well tried in difficult applications. **Fielden Electronics Ltd., Wythenshawe, Manchester.**

BCE 2765 for further information

Magnet Controller

The Unicon RM.3 magnet controller is designed to be particularly suitable for use with D.C. solenoid valves in overcoming operational delay due to residual magnetism. It is automatic and operates either with a manual two-button control or by automatic control from other machinery, contactors, limit switches or sequencing devices, etc. The unit is also applicable to the control of low-current D.C. electro-magnets, clutches, etc. For high-current operation it can be used without any modification to sequence heavy-duty contactors operating, for instance, large lifting magnets. Demagnetisation is automatically initiated on depression of the release button, and continues for a predetermined adjustable time. The unit is interlocked and it is impossible for the operator to re-magnetise until the predetermined demagnetisation period has been completed. The controller is housed in a steel case for wall or flush fitting. **Universal Control Equipment Ltd., 61 Boldmere Road, Sutton Coldfield, Warwicks.**

BCE 2766 for further information

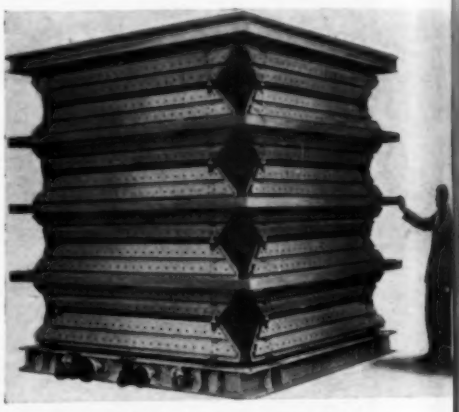
Visual Flow-indicators

Telecator visual flow-indicators made by Dukes & Briggs Engineering Co. are to be distributed solely by Sir W. H. Bailey & Co. under an agreement recently concluded. The indicator has been modified so that it now contains three windows and it can now be supplied in corrosion-resisting metals for special purposes. **Sir W. H. Bailey & Co. Ltd., Patricroft, Manchester.**

BCE 2767 for further information

Collapsible Tanks

Collapsible tanks for transport by road and rail vehicles or by ship of liquids alongside solid freights are being made generally available by Green & Silley Weir after development in conjunction with Marston Excelsior of Wolverhampton. The tanks for road and rail transport are of 850 gallons capacity and the standard size of the ship-borne tank is 8 ft cube. Each is fitted with ample venting connections and a manhole for cleaning, and the tanks can be supplied if necessary with temperature control equipment. New improvements include the



fitting as standard of bags made of either four-ply Fabric-Hycar synethetic rubber to Marston Excelsior specification M.M. 250, or of four-ply fabric/butyl rubber. The leaves are of Kynal M.39/2. The containers are suitable, the makers say, for carrying mineral oils, many chemicals, edible and inedible vegetable oils. Development work is being carried out in the use of the tank for other products, including beer and milk. When empty, the tanks will carry a top loading of 300 psi. **Green & Silley Weir Ltd., 18 London Street, London, E.C.3.**

BCE 2768 for further information

Portable Viscometer

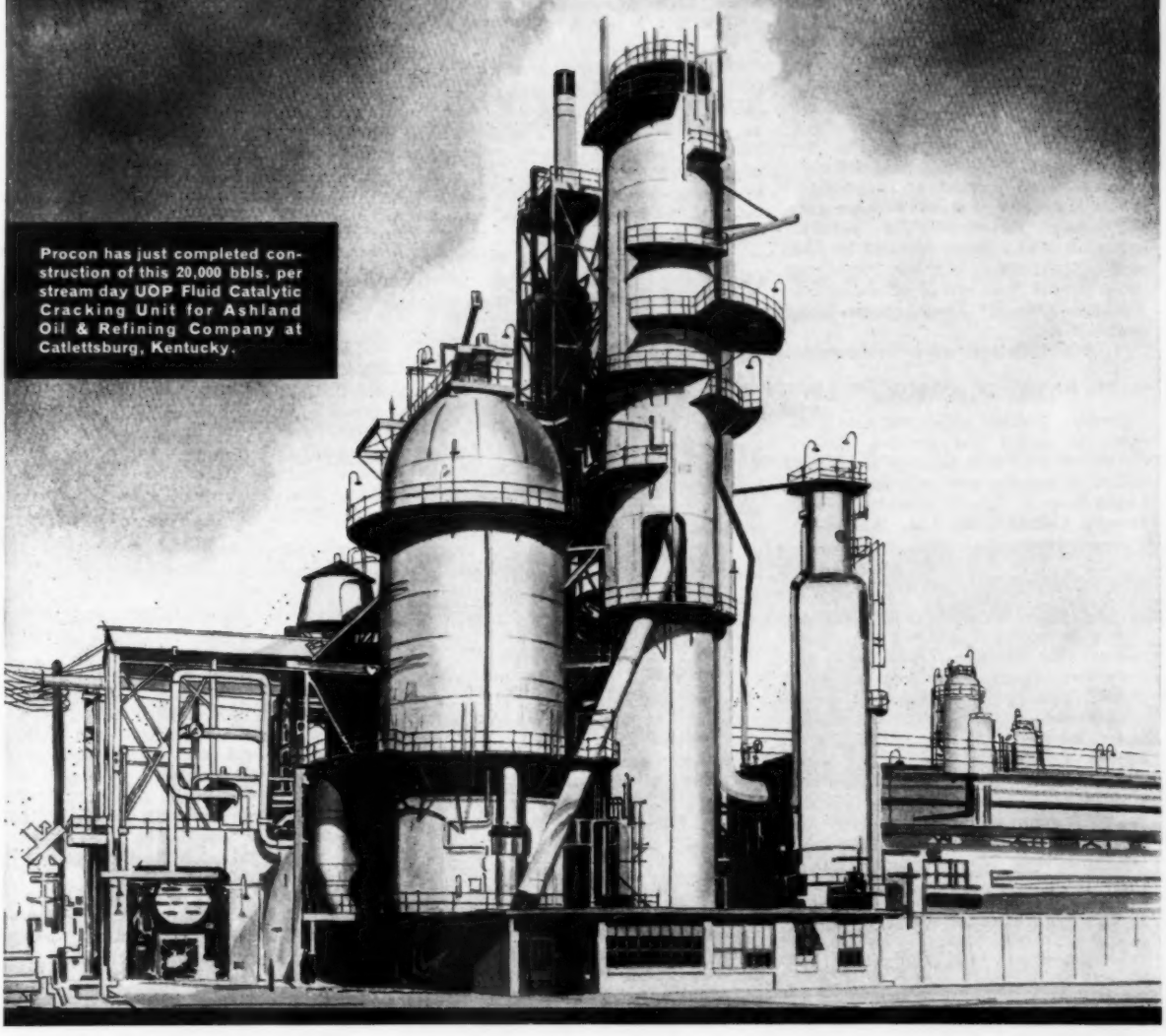
A portable viscometer for the rapid measurement of viscosity in factories and laboratories has been made available by Glen Creston. The instrument consists of a calibrated precision-bore tube surrounded by a metal housing and fitted with a thermometer. Each end of the tube is closed by viewing windows and a mirror at the base allows the operator to determine the time when the sphere contained within the tube, on inversion of the tube, reaches the bottom. The falling time of the sphere multiplied by the sphere constant gives the viscosity in centipoises. The viscometer can be used with dark and opaque liquids. **Glen Creston Ltd., 41 Church Road, Stanmore, Middx.**

BCE 2769 for further information

Air-line Lubricator

A new type of oil-mist lubricator especially designed for use in air-line systems subject to intermittent flow has been developed by Telektron. It is designed to give an initial burst of rich

True satisfaction in building comes only with the finished job



Procon has just completed construction of this 20,000 bbls. per stream day UOP Fluid Catalytic Cracking Unit for Ashland Oil & Refining Company at Catlettsburg, Kentucky.

Here at Procon we take a lot of satisfaction in all phases of our work as builders. Everything we do, from designing and engineering through each stage of construction, gives us that feeling of accomplishment which is so rewarding a part of any job well done.

We only get our fullest measure of satisfaction, though, when the job is finished, faithfully done to every requirement of specification and time.

Procon's experienced organization plans and builds refineries, petrochemical and chemical plants anywhere in the free world. You can count on any project you trust to Procon being completed to your true measure of satisfaction, too.

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oil-air mixture and, thereafter, to reduce the oil content of the mixture and maintain it at a level proportional to the air flow. The lubricators are available with gun-metal or cast-iron bodies, stove enamelled, and they are equipped with transparent oil-bowls of ½-pint capacity. They are being fitted on the company's pneumatic remote-control equipment for valves. This range includes motorising units suitable for operation in the pressure range 3-15 psi; a compact control panel which permits valve adjustment at both high and low speeds together with step-by-step movement and position indication; and a panel operated by two push-buttons, which provides open-close valve control with end-point indication. **Telektron Ltd., 109 Jermyn Street, London, S.W.1.**

BCE 2770 for further information

"Tailor-made" Tanks

Premier Colloid Mills are now prepared to design and produce "tailor-made" tanks up to a capacity of 100,000 gallons of stainless-steel, jacketed, or with dished bases, for clients' special purposes. **Premier Colloid Mills Ltd., Walton-on-Thames, Surrey.**

BCE 2771 for further information

Pocket Radiation Meter

A personal radiation monitor which measures the intensity of radiation in the immediate vicinity of the user and gives audible warning if it exceeds a preset level is being made by Grove Electronics under licence from the U.K. Atomic Energy Commission, and it is being marketed by Fleming Radio. Full use has been made of transistor and printed circuit techniques, the makers say, and the instrument is small and economical in battery power. Standard preset operational levels are 2 and 5 OmR. The battery life is about 45 hours. **Fleming Radio Ltd., Caxton Way, Stevenage, Herts.**

BCE 2772 for further information

Welding by Pyrotechnics

A simple method of welding copper cable to steel or cast-iron in the cathodic protection of pipelines which makes use of a pyrotechnic powder has been elaborated by Metal & Pipeline Endurance. The equipment includes a mould which is held securely in position on the pipe. A metal disc at the bottom of the mould supports the pyrotechnic charge and melts to make up the weld, after the charge is ignited with a flint gun. **Metal & Pipeline Endurance Ltd., Artillery Mansions, Victoria Street, London, S.W.1.**

BCE 2773 for further information

Other Items of Interest

A "C" range of drip-proof motors made to the draft British Standard C.W. (ELE) 6246 has been made available by Brook in the powers ½-50 hp. Particular care, the company points out, has been given to the design of the ventilation system. **Brook Motors Ltd., Huddersfield.**

BCE 2774 for further information

A semi-rigid transparent sheet, Vybak DVB 229, for use in making machine guards, protective screens and windows has been introduced by Bakelite. It is based on polyvinyl chloride resin and is said to be non-inflammable and resistant to water, chemicals and oils. **Bakelite Ltd., 12 Grosvenor Gardens, London, S.W.1.**

BCE 2775 for further information

A new industrial vacuum cleaner which will pick up liquids as well as dust has been introduced by **Martindale Electric Co. Ltd., Westmorland Road, London, N.W.9.**

BCE 2776 for further information

After developing an electrolytic sodium hypochlorite cell for the production of large amounts of chlorine for a specific job, Paterson are making generally available cells having an output of chlorine of 10 lb. an hour, which can be used in duplicate for larger outputs if necessary. They operate with salt solution or seawater. **Paterson Engineering Co. Ltd., Windsor House, Kingsway, London, W.C.1.**

BCE 2777 for further information

Two new humidification machines are now available from Aerosol-Turbo—type W.573 for working spaces of up to 100,000 cu. ft, and type W.561 for spaces of 3000 to 4000 cu. ft. **Aerosol-Turbo Ltd., 14 Cross Belgrave Street, Leeds 2.**

BCE 2778 for further information

A portable 6-volt battery, the 3EN5, which weighs only 3½ lb. and is said to be unspillable in any position, has been added to the Exide range. **Chloride Batteries Ltd., Exide Works, Clifton Junction, Manchester.**

BCE 2779 for further information

Turner & Brown have used a new method of construction for assembling a number of very large p.v.c. acid-resisting fume hoods. The strength of the construction relies on mild-steel tubing which is sealed in the plastic, and special joining-unions allow the framework to be built to any design easily. The hoods can be transported in one section or assembled in sections on the site. **Turner & Brown Ltd., Bolton, Yorks.**

BCE 2780 for further information

Muirhead size 10 servomotors are now in production in Great Britain. The minimum torque at stall for all models is 0.28 oz./in., and the minimum no-load speed 6500 rev. min. **Muirhead & Co. Ltd., Beckenham, Kent.**

BCE 2781 for further information

New Publications

Valves, canned motor pumps and other auxiliaries designed for use in nuclear power plant and a two-element boiler feed regulator are the subjects of two brochures recently issued by **G. & J. Weir Ltd., Cathcart Road, Glasgow, S.4.**

BCE 2782 for further information

New Kent publications include "The Application of Oxygen Analysis to Combustion Control", "Measurement and Automatic Control of *p*H Value in the Paper Industry" and "Instrumentation and Automatic Control of Wet-Process Cement Kilns". **George Kent Ltd., Luton.**

BCE 2783 for further information

The Griffin V.P.C. gas-liquid chromatographic recording apparatus is described in brochure No. P2034 by **Griffin & George Ltd., Wembley, Middlesex.**

BCE 2784 for further information

Lafarge have produced a 32-page booklet for maintenance engineers covering for the first time, they say, four kinds of concrete which may be prepared from their cement. They include corrosion-resistant, refractory and insulating products. **Lafarge Aluminous Cement Co. Ltd., 73 Brook Street, London, W.1.**

BCE 2785 for further information

Equipment for industrial stoving and its use, together with other information including a temperature conversion table, are described in a 32-pp. book published by **A. E. Griffiths Ltd., Booth Street, Birmingham, 21.**

BCE 2786 for further information

British LaBour's new pump brochure describes the company's UPL and UHL horizontal self-priming centrifugal pumps. Miscellaneous conversion data and a table of capacities of the pumps are also provided. **British LaBour Pump Co. Ltd., Blundell Street, London, N.7.**

BCE 2787 for further information

Illustrated booklet No. 55 by Dallow Lambert describes the company's equipment for coping with industrial dust problems. **Dallow Lambert & Co. Ltd., Thurmaston, Leicester.**

BCE 2788 for further information

"Rustodian"—a 22-iminute film in colour just released by Associated Lead for showing to invited audiences—is devoted to their new rust-inhibiting calcium plumbate paint, from which the film takes its name. After describing how the paint was elaborated during the last world war, the film shows with animated diagrams that calcium plumbate paint protects cathodic as well as anodic areas in steel. The use of the paint in covering galvanised iron is also emphasised. **Associated Lead Manufacturers Ltd., Ibex House, London, E.C.3.**

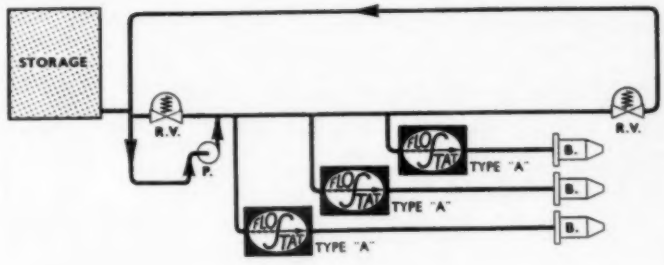
BCE 2789 for further information

Conditaire's latest pamphlet publicises their range of standard refrigeration driers and air conditioners available for use in industry. **Conditaire Ltd., 63 Temple Row, Birmingham, 2.**

BCE 2790 for further information

BCE 2697 for further information

Flostats for Fuel Efficiency



e.g.
Oil flow to burners are set by "FLOSTATS" Type "A," adjustable over 2:1 range with 3-point scale.
Desired flow is accurately maintained irrespective of total oil demand, and of ring main and burner back pressures.

Having measuring and control elements close-coupled in one body, the Flostat gives speedy response and more accurate control. *Overshoot is completely eliminated*, e.g. on open-hearth steel furnace firing. Type "V" Flostats give adjustment of flow setting over 10:1 range but are uncalibrated. Used, in series with flow indicators, as throttles, they provide the least expensive and most accurate method of flow and ratio control of liquids, gases and steam.

Flostats
- **are made in materials for all fluids.**
- **are the key to accurate blending.**
- **prevent waste of service fluids.**
- **improve production efficiency and plant safety**

Write now for information of this remarkable self-acting flow controller.

SOLE MANUFACTURERS: **G. A. PLATON LTD.** Technical Service for Industry
323A, WHITEHORSE ROAD, CROYDON, SURREY. Telephone: THOrnton Heath 1631

Detergent Strength Indicator—

TECHNICAL DETAILS:
Mains supply 200-250V 50-60 c/s.
Sizes: Indicator 9¼ in. x 6½ in. x 5 in.
Electrode 1 ft. 8 in. long x 1½ in. diameter
Weight of Indicator 8 lb.
Weight of Electrode 3 lb.

OPERATION: Warning colour lights are brought into operation when the strength of a detergent bath falls below a preset standard solution.

INSTRUMENT DETAILS: The instrument comprises two units: The ELECTRODE consists of a pair of special grade carbon contacts firmly embedded in an inert plastic moulding, the whole adequately sheathed and protected by a zinc coated iron tube fitted with a suitable adjustable clamp for attachment to the side of the bath or container. The twin cored flexible lead from the electrode is plugged into a socket on the Indicating Unit. To ensure that there can be no danger whatsoever to the operator of the washing equipment sufficiently low potential is used.

The **INDICATING UNIT** consists of a simple yet reliable electronic circuit, the principle of operation being a gas-relay tube responding to resistance changes in the solution and in turn operating a magnetic relay to bring about the change over of the red and green signal lights. Coarse and fine setting-up controls are preset from the front of the panel. The whole unit is enclosed in a light alloy casting with an engraved panel giving operating instructions and carrying indicating lamps, mains switch and fuse unit. A bracket is provided for direct mounting.

Telephone
CROYDON 8282

Gambrell Bros. & Co. Limited
105 - 107, Lansdowne Road, Croydon

BCE 2698 for further information

Month's News in Brief

Engineering at World Fair

Good progress is reported in the building of the British Industry Pavilion at the "Universal and International Exhibition" to be held at Brussels, April 17 to October 19, the first world exhibition to be staged since the war. The pavilion will occupy a large part of the 5-acre British site, and its exhibits, of light and medium engineering, will include a big group-display organised by the Birmingham Engineering Centre in which some 85 firms from all parts of Britain will be represented. Zeta, the experimental machine built at the Atomic Energy Research Establishment, Harwell, for harnessing thermo-nuclear power for industry, may receive bigger prominence at the exhibition than was at first planned. Another nuclear exhibit—a diagram of a typical nuclear marine installation, the first kind of nuclear reactor to be put into operation in Britain by a private company—will be shown by Rolls-Royce. The total of British expenditure on the pavilion, including organisation, construction of the building and stand, and the value of the exhibits is estimated by the Federation of British Industries, who are organising the pavilion, to be £2 to £3 million. Between 35 and 50 million visitors are expected to attend the exhibition.

I.C.I.'s Fellowships Scheme Extended

A number of changes have been made in the I.C.I. scheme of post-doctorate fellowships for research in chemistry, physics, engineering and related sciences, started in 1944. In future the scheme will apply to all universities in the United Kingdom, to the University College of North Staffordshire and to Trinity College and University College, Dublin. The number of fellowships will be increased from 92 to 103, and their value will average £900—an increase of £100 per annum over the old figure. The scheme is guaranteed for five years. The universities and colleges concerned will continue to make the appointments and regulations. The enlarged scheme will cost I.C.I. about £93,000 a year—a sum which raises the company's total contribution to scientific education and research in Great Britain to over £300,000 yearly.

New Development Station

Constructors John Brown Ltd. have established a research and development station at Leatherhead, Surrey, primarily to undertake sponsored development work for Government departments, industrial organisations and the Engineering and Construction Divisions of CJB. Its scope will cover: process development and the investigation of chemical engineering problems; development of automatic control systems and their application; and special problems of nuclear engineering. The station stands on a site of four acres and is equipped with laboratories and pilot-plant building. It has a staff of 30.

Aluminium Welding Advance

A new design of welding head which can handle electric currents of up to 650 amperes for use for welding thick plates of aluminium has been elaborated by the British Welding Research Association. It can be used with conventional aluminium welding equipment. This equipment enables, for example, aluminium 1-in. plates to be welded with only two passes through the welding apparatus at a speed of 12-in. of weld per minute. Special techniques are being developed for handling even thicker plates with a very small number of passes through the equipment.

News Briefs

A scheme to award up to 20 scholarships in civil engineering—valued at between £300 and £400 a year—to boys from families with incomes marginally in excess of £2000 a year who might not otherwise be able to go to university is to be sponsored jointly by the Institution of Civil Engineers, the Association of Consulting Engineers and the Federation of Civil Engineering Contractors.

Durham Raw Materials Ltd. have been appointed distributors in the United Kingdom of materials, including carbon blacks and hard clays, manufactured by the J. M. Huber Corporation, New York.

The Mond Nickel Fellowships Committee invites applications for fellowships of a value of about £900 to £1200 for 1958. Fellowships will be awarded to selected candidates of British nationality with degree or equivalent qualifications. They are intended to enable the holders to obtain wider experience and additional training in industrial establishments, at home or abroad, to make them more suitable for future employment in senior technical and administrative positions in British metallurgical industries. Applicants will be required to state details of the programme they wish to carry out. Forms of application are available from The Secretary of the Committee, 4 Grosvenor Gardens, London, S.W.1, and they are required to be returned completed by June 1.

The installation of a digital computer for Durham University has been completed. It has been built at Kensington Terrace, Newcastle upon Tyne, adjoining the university office, and it will serve both the Durham and Newcastle divisions of the university.

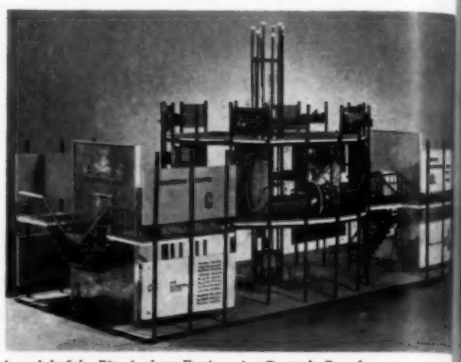
The theme of the tenth British Electrical Power Convention to be held at Brighton from June 16 to 20 will be "Electricity and World Progress: Britain's Contribution". The president will be Sir George Nelson. An Electrical Exhibition is to be held in conjunction with the Convention.

R. & H. Green & Silley Weir Ltd. have removed to 18 London Street, London, E.C.3. Telephone ROYal 8511.

An extension to the research and development department of British Glues & Chemicals Ltd. was opened at the group's Bermondsey, London, factory recently. The new accommodation also houses the recently-formed biochemical research department.

Birfield Industries Ltd. have formed an engineering division to co-ordinate the selling activities of the Birfield Group.

A Belgian branch office of Evershed & Vignoles Ltd. is to be opened at Succursale, 142 rue Gallait, Brussels.



A model of the Birmingham Engineering Centre's Stand in the British Industry Pavilion at the Brussels Exhibition on which 85 firms from the light and medium engineering industries will display their products.

The newly-formed Yorkshire Imperial Metals Ltd. represents a fusion of the copper and alloy tube, fittings and plate activities of the Yorkshire Copper Works Ltd. and of Imperial Chemical Industries Ltd. The company disposes of assets worth about £18 million including the former I.C.I. plants at Kirkby (Liverpool), Smethwick, Landore (Swansea) and Dundee, and the former Yorkshire Copper plants at Leeds, Barrhead (Glasgow) and Castleford, Yorks. Its registered office is at Haigh Park Road, Leeds.

The planning committee of London County Council has approved the plans for the central part of the scheme for the Imperial College of Science and Technology, London, including the bell tower facing Imperial Institute Road. Plans for the east and west blocks had previously been approved.

A 52-ft-long stainless-steel distillation column filled with Glitsch truss-type bubble trays for the Acrilan fibre plant of Chemstrand Ltd. being loaded on to the Preston-Larne ferry on its way to Coleraine, Northern Ireland. It is one of three being built by Metal Propellers Ltd.

TONNAGE OXYGEN AND GAS SEPARATION PLANT

NEW INSTALLATIONS

AT SHELLHAVEN ON THE THAMES ESTUARY

The British Oxygen Linde plant is in course of erection. Plant capacity: 240 tons of oxygen and 235 tons of nitrogen a day for the manufacture of ammonia.

FOR SHELL CHEMICALS AT PARTINGTON, LANCS

Work on this plant for the direct oxidation of ethylene will shortly be completed. British Oxygen Linde plant capacity: oxygen 145 tons a day, nitrogen 55 tons a day.

FOR THE IRON AND STEEL WORKS AT DURGAPUR

in India. An order has recently been placed with British Oxygen Linde to supply 2 Tonnage Oxygen units with a total capacity of 100 tons a day.

FOR THE IRON AND STEEL WORKS AT ROUKELA

in India. 3 British Oxygen Linde units have been ordered, each with a capacity of 100 tons of oxygen a day.

FOR AFRICAN EXPLOSIVES AND CHEMICAL INDUSTRIES LIMITED

at Modderfontein. British Oxygen Linde plant has been ordered with a daily output of 275 tons of oxygen and 285 tons of nitrogen for the manufacture of ammonia.

BRITISH OXYGEN LINDE LIMITED

OUR EXPERIENCE IS AT YOUR SERVICE

If you are thinking of installing tonnage oxygen or gas separation plant, consult BRITISH OXYGEN LINDE. Our advice is free and your enquiries, however preliminary, will be welcome.

BRIDGEWATER HOUSE, CLEVELAND ROW, ST. JAMES'S, LONDON S.W.1. Tel: WHI 1688

People in the News

B. W. Jesser

J. M. Carry

R. Y. Parry

J. S. Epstein

Mr. B. W. Jesser has been appointed manager of Kellogg International Corp., London. Previously he was a contract operations staff engineer and manager of Kellogg's design engineering department, and earlier was an instructor in chemical engineering at Princeton University. He will relieve **Mr. F. E. Johnson, jun.**, who has been appointed an assistant engineering vice-president of M. W. Kellogg. **Mr. James M. Carry** has been elected vice-president of M. W. Kellogg Co., New York. He joined the company in 1954 as assistant to the president, after three years in a similar post with Pullman.

New members of the staff of Foxboro-Yoxall, Merton, include **Mr. A. E. Parritt**, contracts engineering manager, and **Mr. D. Phelps**, manager of the application engineering department.

Isotope Developments Ltd. have appointed **Mr. R. Y. Parry** technical manager. Mr. Parry was chairman of the Nucleonics Group, S.I.M.A., 1955-57, and he is a member of the B.S.I. committee on Glossary of Terms Used in Nuclear Science. **Mr. J. S. Eppstein**, head of the electronics division of the company since he joined it in 1951, has been appointed chief engineer of the company. Previously his experience included four years in the Nuclear Physics Division at A.E.R.E., Harwell.

Albright & Wilson Ltd. have appointed **Mr. W. Carter** a director. He has been managing director of the operating company, Albright & Wilson (Mfg.) Ltd., since its formation last year.

Mr. John Kerr-Muir, who recently completed a period of office as executive vice-president of Courtaulds (Canada) Ltd., and **Mr. Arthur William Knight** have been appointed directors of Courtaulds Ltd. **Mr. D. C. F. Devos**, managing director of Courtaulds Chemicals Division, retired recently after 38 years' service with Courtaulds, most of which had been devoted to chemical and viscose-rayon manufacturing. He started at the company's Trafford Park sulphuric acid and carbon disulphide works in 1920, and in the 1930s, after managership in France, designed new viscose-rayon processing equipment. Since the war he played a leading part in developing sulphuric acid and carbon disulphide processes. Mr. Devos was a director of the United Sulphuric Acid Corporation, the British Sulphur Corporation and the Sulphur Exploration Syndicate.

Mr. L. E. Nichols has resigned his post as north-east area engineer of the National Industrial Fuel Efficiency Service and is proposing to re-enter consulting engineering practice. For the time being, **Mr. George Gill**, north-west area engineer, will exercise general supervision over the Leeds, Sheffield and Newcastle offices, in addition to his other duties.

Mr. G. Hickson and **Mr. W. Woodhall** have been appointed directors of Laporte Industries. Mr. Hickson is returning from Australia to take up the position of managing director of Laporte Chemicals, and Mr. Woodhall will continue as managing director of Laporte Titanium. **Mr. W. S. Duffield** has been appointed managing director of Laporte Chemicals (Australia) Proprietary.

Mr. A. R. Mathias has been appointed chairman of the Lead Development Association for 1958. He succeeds **Mr. H. L. Evans**, who had held this office since January, 1956.

Sir Alexander Gibb, G.B.E., C.B., F.R.S., founder of Sir Alexander Gibb Partners, consulting engineers, died at his home at Hartley Wintney on January 21 aged 85. He was president of the Institution of Chemical Engineers 1927-8.

Meetings of the Month

Institution of Chemical Engineers

February 19. *Midlands Centre:* At Chemical Engineering Lecture Theatre, Birmingham University. "The Instrumentation of Modern Chemical Plant." **6.30 p.m.**

February 19. *South Wales Centre:* At Glamorgan Technical College. "The Homogeneous Aqueous Reactor. **7 p.m.**

February 25. *North-Western Branch:* At Birkenhead Technical College. "Ion Exchange as a Unit Operation." **7 p.m.**

February 28. At Caxton Hall, Westminster, London, S.W.1. "Project Cost Estimation." **6.30 p.m.**

March 4. At The Hoare Memorial Hall, Church House, London, S.W.1. Spring meeting and "A Contribution to the Theory and Practice of Granulation". **Whole day.**

March 5. *Midlands Branch:* At the Midland Institute, Paradise Street, Birmingham. "Flow of Granular Materials through Orifices." **6.30 p.m.**

March 6. *East Midland Centre:* At Main Lecture Theatre, Loughborough College of Technology. "Economic Aspect of Scale-up." **7 p.m.**

March 12. *North Western Branch:* At Chemistry Department, Lecture Theatre, Leeds University. "Sulphuric Acid from Anhydrite at Whitehaven." **7 p.m.**

March 18. *North Western Branch:* At Reynolds Hall, College of Science and Technology, Manchester. "Heat Transfer in Relation to Nuclear Engineering." **7 p.m.**

March 19. *South Wales Centre:* At University College, Cardiff. "Gas/Solid Reactions in Fluidised Beds." **7 p.m.**

Royal Society of Arts

February 19. At John Adam Street, Adelphi, London, W.C.2. A paper on Rocket Propulsion. **2.30 p.m.**

Institution of Mechanical Engineers

February 21. At 1 Birdcage Walk, Westminster, London, S.W.1. "Packed Glands for High Pressures; an Analysis of Fundamentals", and "Glands for the Entry of Electrical Cables into Pressure Vessels Containing or Surrounded by Liquids. **6 p.m.**

March 4. *Applied Mechanics Group:* At 1 Birdcage Walk, Westminster, London, S.W.1. Discussion: "Mathematics in Mechanical Engineering". **6 p.m.**

March 6. *Education Group:* At 1 Birdcage Walk, Westminster, London, S.W.1. Discussion: "How Should Liberal Studies be Dealt with in Technical Colleges. **6 p.m.**

Institution of Civil Engineers

February 25. At the Institute, Great George Street, Westminster, London, S.W.1. "Prestressed-concrete Cylindrical Tanks." **5.30 p.m.**

Society of Instrument Technology

February 26. *Chester Section:* At Board Room of the Chester and District Hospital Management Committee, 5 King's Buildings, King Street, Chester. "Instrument Manufacture." **7 p.m.**

March 11. *Manchester Section:* At Manchester College of Technology. "Experience with Instruments at Calder Hall Power Station." **7.30 p.m.**

Institute of Metals

February 26. At the College of Technology, Costa Green, Birmingham. All-day Informal Discussion on "Fuel Efficiency in the Melting and Thermal Treatment of Metals".

Society of Glass Technology

March 3. *Midlands Section:* At the Talbot Hotel, Stourbridge. "Safety Glass Yesterday, Today and Tomorrow." **6.30 p.m.**

Society of Chemical Industry

March 11. *Chemical Engineering Group:* At 14 Belgrave Square, London, S.W.1. "Kachkaroff Process for Sulphuric Acid Manufacture" and "Constructional Details of a Petersen Tower Sulphuric Acid Plant". **5.30 p.m.**

Physical Society

March 13. *Low Temperature Group:* At 1 Lowther Gardens, Prince Consort Road, London, S.W.7. "Molecular Sieves."